# CHAPTER 3: WILLAMETTE BASIN MERCURY TMDL

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# *OVERVIEW*

The bioaccumulation of mercury in fish is a well recognized environmental problem throughout much of the United States. The number of states that have issued fish consumption advisories pertaining to mercury has risen steadily from 27 in 1993 to 45 in 2002 (USEPA, 2003). The Oregon Department of Human Services (DHS) has issued multiple fish consumption advisories for mercury in the Willamette Basin (DHS, 1993, 1997a, 1997b, 2001, 2004a, 2004b) advising consumers of fish of the health risks associated with eating fish caught from the Willamette River and the Dorena and Cottage Grove Reservoirs. These fish consumption advisories represent an impairment of the beneficial use of fishing in the Willamette Basin and demonstrate that mercury is bioaccumulating in fish tissue to levels that adversely affect public health. The TMDL for mercury, described below, is designed to restore the beneficial use of fish consumption to the Willamette River and its tributaries.

One of the primary goals of this TMDL is to establish an interim water column guidance value deemed to be protective of the beneficial use of fish consumption in the Willamette Basin. This interim guidance value, when attained, should eventually reduce the concentrations of mercury in fish tissue to levels that no longer pose an unacceptable health risk to consumers of the fish. This TMDL document describes the methodology utilized in establishing the interim water column guidance value as well as the sector-specific load reductions necessary for the eventual attainment of the guidance value concentration. The corresponding Water Quality Management Plan (WQMP) outlines the implementation strategy that will promote mercury reductions throughout the Basin, the eventual attainment of the established water-column guidance values and, ultimately, the restoration of the beneficial use of fish consumption. The goals and objectives of this TMDL are consistent with the requirements of the federal Clean Water Act, Oregon's Administrative Rules, and ODEQ's Mercury Reduction Strategy (ODEQ, 2003a).

ODEQ acknowledges the current limitations to our understanding of the fate, transport, bioaccumulation, loading and sources of mercury in the Willamette Basin. These limitations have the potential to influence the estimates of the loading of mercury in the Willamette system, the sector-specific source contributions, the water column guidance values, as well as the estimated reductions necessary to restore the beneficial use of fish consumption. For this reason, ODEQ is establishing *interim* water column guidance values and sector-specific allocations at this time, based on the collected body of information currently available. The preliminary sector-specific allocations will not be translated into numeric water quality based effluent limits for individual point sources at this time. The interim targets and allocations will be used to define the extent of the problem and to identify the level of effort needed to address the bioaccumulation of mercury in fish. ODEQ intends to require specified domestic and industrial point sources in the Willamette Basin to monitor their effluent for mercury and to submit their data to ODEQ. Mercury minimization plans will also be required from select sources and sectors. These minimization plans will serve as the primary vehicle for implementing mercury reduction activities within the point source sector. Nonpoint sources will also be expected to incorporate mercury concerns into the established mechanisms for TMDL implementation pertaining to agriculture, forestry, and urban land use activities. This incremental approach for the mercury TMDL is warranted due to the assumptions and limitations of the currently available information. ODEQ believes that the interim approach described in this chapter is consistent with State and Federal law and meets the specific requirements of TMDLs as presented in Table 3.1.

ODEQ plans to develop *revised* estimates of the water column guidance values and allocations by 2011. At that time, ODEQ will have the opportunity to translate the revised allocations into water quality based effluent limits for wastewater point sources. In the interim, ODEQ will develop a comprehensive conceptual framework for assessing mercury behavior in the Basin, along with the methodological and modeling tools needed to calibrate and validate this framework. To provide data for this purpose, ODEQ will: (1) conduct three years of water quality monitoring to collect additional information on ambient mercury and methyl mercury concentrations and (2) perform additional source characterization work to help refine the estimates of sector-specific source contributions. ODEQ looks forward to working with stakeholders during the next incremental phase of this effort to obtain the resources and the funding necessary to undertake this work in a timely and efficient manner. The availability of the expanded data set will help reduce uncertainties and enable the development of more refined estimates of the appropriate water column guidance values and sector-specific load and wasteload allocations. ODEQ also commits to the further evaluation of the methodological and modeling tools employed in this study (as presented in detail below). In the event new information suggests improved alternative methods for establishing water column guidance values and/or load allocations, this information will be incorporated into the 2011 revisions as part of the iterative adaptive management framework.

Over the course of the past four years ODEQ has been working with a group of stakeholders to discuss key policy issues related to the development of the mercury TMDL. This group, known as the Willamette River TMDLs Council has met approximately every other month since March, 2001. The sectors and entities represented by this Council include industry, U.S. Army Corps of Engineers (USACE), environmental groups, the Association of Clean Water Agencies, forestry, agriculture, developers, recreational and commercial fishermen, public utilities, and the Tribes. The group was facilitated by an independent facilitator and staffed by ODEQ. Agendas and meeting summaries for this group can be found on ODEQ's website: http://www.deq.state.or.us/wq/willamette/WRBHome.htm . The Council provided valuable input to ODEQ on key issues such as: the use of the food web model to determine interim water column guidance values; the establishment of guidance values in units of total mercury as opposed to methyl mercury; the choice of fish species utilized in the establishment of water column guidance values; the methodology to assess the load and sources of mercury within the Willamette Basin; the determination of data adequacy for the development of interim mercury allocations; and the elaboration of the 'path forward' to address continued monitoring and model development needs. Each of these issues will be discussed in detail within the text of this chapter. Whereas the Council was a valuable sounding board for ODEQ on these key issues, providing much valuable information and reactions, the group did not often reach consensus. The feedback from the group, however, significantly aided ODEQ in reaching complex technical and policy decisions. The TMDL for mercury reflects significant input from Council members and their constituent groups and ODEQ is grateful to members of this group for their participation. The policy decisions outlined in this TMDL, however, do not necessarily represent endorsement by the Willamette River TMDLs Council.

This mercury TMDL is being developed for the entire Willamette Basin which includes the Clackamas, Coast Fork Willamette, Lower Willamette, McKenzie, Middle Fork Willamette, Middle Willamette, Molalla-Pudding, North Santiam, South Santiam, Tualatin, Upper Willamette, and Yamhill Subbasins. The area affected by this TMDL for mercury is different from the area covered by the temperature and bacteria TMDLs. The bacteria and temperature TMDLs presented in this document cover a smaller geographical area since they do not address waterbodies in the Molalla-Pudding, Tualatin, and Yamhill Subbasins.

**Table 3. 1 Mercury TMDL Components.**

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| **Waterbodies**<br>***OAR 340-042-0040-4(a)*** | This TMDL covers all tributaries to the Willamette River Basin (Hydrologic Unit Code (HUC) 170900). Water quality-limited stream segments for mercury include the entire mainstem Willamette River (from the mouth to the confluence of the Middle Fork and Coast Fork Willamette Rivers), the Coast Fork Willamette (HUC 17090002) from the mouth to the Cottage Grove Reservoir, and the Dorena and Cottage Grove Reservoirs (in the Coast Fork Willamette Subbasin). |
| **Pollutant Identification**<br>***OAR 340-042-0040-4(b)*** | Anthropogenic increases in instream mercury concentrations. |
| **Beneficial Uses**<br>***OAR 340-042-0040-4(c)***<br>***OAR 340-041-0340*** | Fishing is one of the designated beneficial uses of the Willamette Basin (as indicated in Table 340A). This TMDL focuses on the restoration of the beneficial use of fish consumption in the Willamette Basin. |
| **Criteria Identification**<br>***CWA §303(d)(1)***<br>***OAR 340-042-0040-4(c)*** | **OAR 340-041-0340:**<br>Water quality in the Willamette Basin must be managed to protect a range of beneficial uses including fishing.<br>**OAR 340-041-0033:**<br>(1) Toxic substances may not be introduced above natural background levels in waters of the state in amounts, concentrations, or combinations that may be harmful, may chemically change to harmful forms in the environment, or may accumulate in sediments or bioaccumulate in aquatic life or wildlife to levels that adversely affect public health, safety, or welfare or aquatic life, wildlife, or other designated beneficial uses.<br><br>(2) Levels of toxic substances in waters of the state may not exceed the applicable criteria listed in Tables 20, 33A, and 33B. Tables 33A and 33B, adopted on May 20, 2004, update Table 20 as described in this section.<br>(a) Each value for criteria in Table 20 is effective until the corresponding value in Tables 33A or 33B becomes effective.<br>(A) Each value in Table 33A is effective on February 15, 2005, unless USEPA has disapproved the value before that date. If a value is subsequently disapproved, any corresponding value in Table 20 becomes effective immediately. Values that are the same in Tables 20 and 33A remain in effect.<br><br>*[Note that to date, USEPA has neither approved nor disapproved Oregon's revised toxics criteria.]*<br>(B) Each value in Table 33B is effective upon USEPA approval.<br>(b) The department will note the effective date for each value in Tables 20, 33A, and 33B as described in this section.<br><br>(3) To establish permit or other regulatory limits for toxic substances for which criteria are not included in Tables 20, 33A, or 33B, the department may use the guidance values in Table 33C, public health advisories, and other published scientific literature. The department may also require or conduct bio-assessment studies to monitor the toxicity to aquatic life of complex effluents, other suspected discharges, or chemical substances without numeric criteria. |
| **Existing Sources**<br>***CWA §303(d)(1)***<br>***OAR 340-042-0040-4(f)*** | Source categories considered in this TMDL include: legacy mines, industrial and municipal point sources, sediment resuspension, native soil erosion, stormwater runoff, and the atmospheric deposition from point, area, mobile and global sources. |
| **Seasonal Variation**<br>***CWA §303(d)(1)***<br>***OAR 340-042-0040-4(j)*** | There are considerable seasonal variations in the mass loads and concentrations of the various forms of mercury present in the Willamette Basin. Mass loads of total mercury were highest during the winter months due primarily to seasonal variations in flow rate. During high flow events, increases in soil erosion and resuspension of bed sediments combine to produce elevated total mercury concentrations. Concentrations of methyl mercury, on the other hand, were typically lowest during the winter months (at or near method reporting and detection levels) when the total mercury concentrations were highest. Seasonal variations in methyl mercury concentrations are due in part to the influence of temperature, sunlight and other parameters that affect the rate of mercury methylation and demethylation. |
| **TMDL Loading Capacity and Allocations**<br>***40 CFR 130.2(f)***<br>***40 CFR 130.2(g)***<br>***40 CFR 130.2(h)***<br>***OAR 340-042-0040-4(d), 4(e), 4(g), 4(h)*** | The interim loading capacity of 94.6 kg/yr represents the total annual load of mercury (as calculated at the mouth of the Willamette River) associated with the water column guidance value concentration deemed to be protective of the beneficial use of fish consumption. The interim loading capacities for the Dorena and Cottage Grove watersheds are 1.46 and 1.01 kg/yr respectively.<br><br>For the mainstem Willamette River, Wasteload Allocations (WLA) for Point Sources total 3.7 kg/yr and Load Allocations (LA) for Nonpoint Sources total 90.1 kg/yr. There are no significant point sources of mercury above the Dorena and Cottage Grove Reservoirs. For this reason, the LAs for nonpoint sources are equal to the loading capacities of each of the two systems (1.46 and 1.01 kg/yr) for the Dorena and Cottage Grove watersheds, respectively. |

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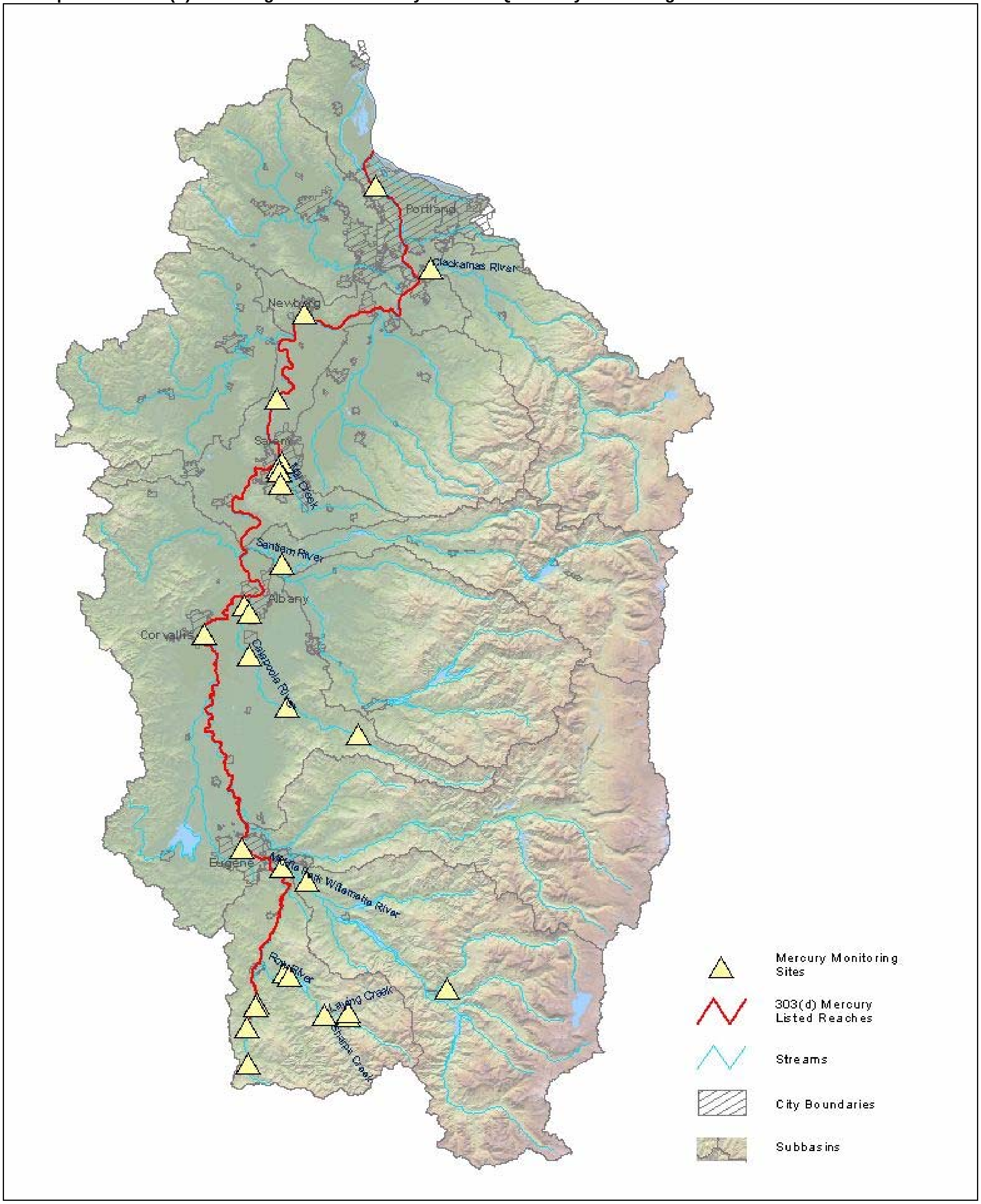
|---|---|
| **Surrogate Measures**<br>***40 CFR 130.2(i)***<br>***OAR 340-042-0040-5(b)*** | Surrogate measures are developed to translate the point source wasteload allocations and the nonpoint source load allocations into terms of the percent reductions needed to achieve the interim water column guidance value. These surrogate measures effectively translate average annual loads of mercury into more applicable measures of performance. The estimated percent reductions needed to attain the interim water column guidance value are 26.4%, 29.8%, and 67.8% for the mainstem Willamette River system, the Dorena Watershed and the Cottage Grove Watershed, respectively. |
| **Margins of Safety**<br>***CWA §303(d)(1)***<br>***OAR 340-042-0040-4(i)*** | The Food Web Model employed in this TMDL utilizes a fish tissue criterion of 0.3 mg/kg in establishing an interim water column guidance value. Oregon's fish consumption advisories are issued by the DHS when the average fish tissue concentrations of mercury exceed the threshold of 0.35 mg/kg. The use of 0.3 mg/kg in our analysis, as opposed to 0.35 mg/kg, represents a conservative margin of safety on the order of fifteen percent and is consistent with recently developed guidance from the USEPA.<br><br>The utilization of the northern pikeminnow in the development of the interim water column guidance value also has an inherent degree of conservatism due to the fact that the northern pikeminnow is the most efficient bioaccumulator of mercury considered in our analysis. It is recognized that this particular fish species is not targeted by commercial fishermen in the Willamette Basin. The northern pikeminnow, however, may be caught and consumed on an occasional basis by recreational and or subsistence fishermen. In selecting a guidance value based on the northern pikeminnow, we have chosen one that would also be protective of the consumers of other fish species found in the Willamette which may be more readily targeted for human consumption. |
| **Reserve Capacity**<br>***OAR 340-042-0040-4(k)*** | A small reserve capacity of 0.8 kg/yr (0.6% of the total load) has been incorporated into this TMDL to allow a growing municipality or a new source to discharge effluent containing low levels of mercury. The establishment of this reserve capacity would allow growth and expansion to occur in the Basin. This small allocation set aside as a reserve capacity is warranted due to the significant reductions in mercury loading which have and are currently occurring throughout the Basin and the low likelihood of new future releases. |
| **Water Quality Management Plan**<br>**OAR 340-042-0040(4)(l)** | The Water Quality Management Plan (WQMP) provides the framework of management strategies to attain and maintain water quality standards. The WQMP is designed to complement the detailed plans and analyses provided in specific implementation plans. See Chapter 14. |

**Map 3.1 303(d) listed segments for Mercury and ODEQ Mercury Monitoring Sites in the Willamette Basin.**



## Mercury in the Environment

Mercury is a naturally occurring element found in cinnabar deposits and areas of geothermal activity. In Oregon, mercury was mined commercially and used extensively in gold and silver amalgamation (Brooks, 1971; Park and Curtis, 1997). Mercury has been used historically in fungicide formulations and can still be found in many commercial products including fluorescent lights, thermometers, automobile switches and dental amalgam. Mercury is also naturally present in trees and fossil fuels such as coal, natural gas, diesel fuel and heating oil. The mercury present in these fuel sources is released into the atmosphere upon combustion. This atmospheric mercury can be transported great distances and is known to be deposited on the landscape via either wet or dry deposition (Sweet *et al*., 1999, 2003).

Mercury can be present in various physical and chemical forms in the environment (Ullrich *et al.,* 2001; USEPA, 2001b). The majority of the mercury found in the environment is in the form of inorganic or elemental mercury but these forms of mercury can be converted to organic or methyl mercury by sulfate-reducing bacteria. Methyl mercury production is affected by a host of physical and chemical factors including temperature, redox potential, dissolved oxygen levels, organic carbon, sediment particle size, alkalinity, sulfate concentration and pH. Methyl mercury, once formed, represents the most bioaccumulative form of mercury in fish tissue and the most toxic form of mercury for human consumers (USEPA, 2001a).

Methyl mercury is a potent neurotoxin that has the potential to cause permanent damage to the brain, kidney, and developing fetus (ATSDR, 1999). Effects on brain functioning may cause irritability, shyness, tremors, changes in vision or hearing and memory problems. Children are known to be more sensitive than adults to mercury intoxication. The mercury present in the mother’s body may pass to the fetus and accumulate there. It can also pass to a nursing infant through breast milk. Mercury’s harmful effects to children include brain damage, mental retardation, incoordination, blindness, seizures and inability to speak. The primary route of human exposure to mercury is via the consumption of fish or seafood containing elevated levels of mercury (USEPA, 2001a).

# Summary of Mercury TMDL Development and Approach

The stated objective of this TMDL is to reduce average fish tissue mercury concentrations in the Willamette River so that the fish are safe for human consumption. The multiple fish consumption advisories for mercury in the Willamette Basin and the numerous 303(d) listings indicate that this beneficial use is not currently being met. ODEQ acknowledges that it may take many years, perhaps even decades, to ultimately achieve the desired reduction in fish tissue concentrations of mercury. In establishing interim water quality guidance values, ODEQ has considered the criteria and thresholds utilized by the DHS when issuing fish consumption advisories. This TMDL analysis is *not* designed to reevaluate the levels of mercury deemed safe for human consumption or to revisit the basic assumptions inherent in DHS's risk assessment analysis for mercury (see Appendix B for a complete description of the methodology employed by DHS when issuing fish consumption advisories pertaining to mercury). The proposed TMDL outlined in this document is also not explicitly structured to address ecological receptors, as the focus of this effort has been on the human health concerns pertaining to the multiple fish consumption advisories. If, at some point in the future, data from the Willamette Basin indicate that other sensitive ecological species are being adversely affected by mercury contamination (leading to additional 303(d) listings), then ODEQ would most likely address this impairment through a future TMDL. The TMDL is also not designed to address the drinking water criterion for mercury as that numeric criterion (0.002 mg/l) has not been exceeded.

ODEQ's approach to the mercury TMDL is based on two fundamental methodological components: a Basin-Specific Aquatic Food Web Biomagnification Model for the Estimation of Mercury Target Levels; and an independent Revised Estimate of a Mercury Mass Balance for the Willamette River Basin. A basin-wide mercury monitoring program was also implemented to support the development of the food web model and to estimate mercury mass loads and sources. The discussion below contains a more detailed technical presentation of the analytical tools utilized in the development of this mercury TMDL.

## *Food Web Biomagnification Model (FWM)*

A basin-specific aquatic Food Web Model (FWM) was employed to establish a range of interim guidance values for total mercury in surface water that are linked to the protection of the beneficial use of fish consumption (see Appendix B). The estimation of target water concentrations requires a biomagnification factor and a fish tissue criterion deemed to be protective of human health. The USEPA recommends that for a particular area of concern, biomagnification factors derived from data collected within the area of study are more preferable than the utilization of standardized default values (USEPA, 2001b). They also suggest inclusion of site-specific considerations when calculating surface water guidance value levels. ODEQ's model for the Willamette Basin was employed to bring regional specificity to estimates of biomagnification factors and mercury guidance values. The FWM focused on resident fish species identified as species of concern in the DHS Fish Consumption Advisories, those occupying critical niches in the aquatic food web, or those species of particular concern to stakeholders in the Basin. The FWM was calibrated with basin-specific fish tissue and water quality data.

The FWM simulates mercury accumulation in fish, via a basin-specific food web, considering chemical mass balances for aquatic biota. The model was calibrated with fish tissue, sediment and surface water mercury data from the Willamette Basin. The model developed for this study considers the direct uptake of the chemical from water, uptake through feeding, loss of the chemical due to elimination, and dilution as a function of age. The FWM addresses the potential for bioconcentration, bioaccumulation, and biomagnification. In order to predict tissue levels in fish destined for human consumption, the model is repeatedly applied to organisms at each trophic level to simulate mercury transfer from primary and secondary producers, through a variety of intermediate fish species, to top level predacious fish. Probabilistic (Monte Carlo) techniques were used to propagate stochastic variability and incertitude throughout the model to provide a range of estimates for the mercury guidance values. Empirical data from the Willamette Basin was used to estimate the relative ratio of dissolved methyl mercury to total mercury in the water column. This translator was used to establish water column guidance values based on units of total mercury, recognizing that it is the methylated form of mercury that is actually prone to bioaccumulation. The empirically-derived translators utilized in this study were consistent with default values proposed by the

USEPA (USEPA, 2001b). Several mercury guidance values were generated for each fish species varying in their probability of affording human health protection relative to the USEPA's established fish tissue criterion of 0.3 mg/kg. The FWM developed for the Willamette Basin has been peer reviewed and published in *Environmental Toxicology and Chemistry* (Hope, 2003).

## Estimate of Mass Loads and Sources

The mercury mass balance analysis compares the estimated mass of total mercury discharged from the Basin as fluvial load (output) to the sum of estimated contributions from a variety of potential mercury sources (inputs) either internal or external to the Basin. The fluvial load (output) was estimated by first developing a relationship between flow and river mile (RM). This relationship was then used to estimate the flow at locations lacking recent U.S. Geological Survey (USGS) flow data. Ultra low-detection mercury concentration data from the ODEQ and various municipalities in the Willamette Basin were then matched (both spatially and temporally) with flow data to form a relationship between flow and concentration. Finally, using a distribution of daily flow rates developed with USGS data, the average annual mass of mercury leaving the Basin at the confluence (river mile 0) was estimated as a function of flow and concentration. Available data and informed assumptions were used to identify and quantify possible sources of mercury with respect to the Basin. Mean estimates of relative mass contributions were developed for each of the following source categories: erosion of mercury-containing soils, runoff of atmospherically deposited mercury, landfill emissions, historical mining activities, municipal and industrial point sources, stormwater, and sediment resuspension. The results of the mass balance analysis (Appendix B) helped inform ODEQ's proposed framework for allocations and reductions presented below.

Significant data gaps and assumptions limit our ability to accurately estimate the magnitude of source-specific mercury contributions. Emission and effluent data from air and water point sources are still limited, as are specific data on total and methylmercury concentrations from municipal and industrial sources in the Willamette Basin. Limited data exist for municipal point sources but many of these data lack the required analytical precision (i.e., use of low detection limit methods for total mercury and methylmercury) necessary to make an accurate estimate of the magnitude of their contributions. There is also limited site-specific information on sediment resuspension, the degree of runoff of mercury associated with various land use categories, and the extent of wet and dry atmospheric deposition. Data gaps hindering this mass balance analysis were bridged with values taken from the literature and with plausible assumptions regarding the behavior of mercury in the Willamette Basin system. The activities and commitments outlined in the WQMP will help generate additional information for the further refinement of these initial estimates of mercury loading and sector-specific source contributions during the next incremental phase of this effort.

## Ambient Mercury Monitoring Program

The Willamette River is a large and diverse system that has many potential sources of mercury and a range of habitats differentially affecting methyl mercury production and bioaccumulation in fish. River morphology can affect many of the physical-chemical characteristics that influence methyl mercury production. The river morphology changes from a high-energy stream in the headwaters to a tidally influenced river near the mouth. Therefore, a basin-wide mercury monitoring program was implemented to support the development of the food web model and to estimate mercury mass loads and sources (ODEQ, 2002). The monitoring for both total and methyl mercury in the water column and sediment, as well as total mercury in fish, was made possible by a grant from USEPA. USEPA also provided considerable 'in-kind' services over the course of this project by offering technical assistance and by conducting the analytical analyses required for the measurement of mercury and other parameters in water, sediment and fish tissue.

Eighteen sites in the Willamette Basin were monitored on a quarterly basis for methyl mercury and total mercury in the water column during 2002 and 2003 (Map 3.2 and Table 3.2). Sediment samples were also collected and analyzed for mercury and methyl mercury. In addition, fish were collected from selected sites in the Willamette River (and the two reservoirs) and were submitted to the USEPA laboratory for mercury analysis. A reference site on the Middle Fork Willamette River above the Hills Creek Reservoir was selected as a background site for the basin. This site consistently recorded low levels of mercury (both total mercury and methyl mercury) in the water column. Data presented in Appendix B were used to calibrate and validate the FWM, calculate the average loads of mercury in the mainstem Willamette River, and estimate source contributions by sector.

**Map 3.2 Mercury Monitoring Sites in the Willamette Basin**

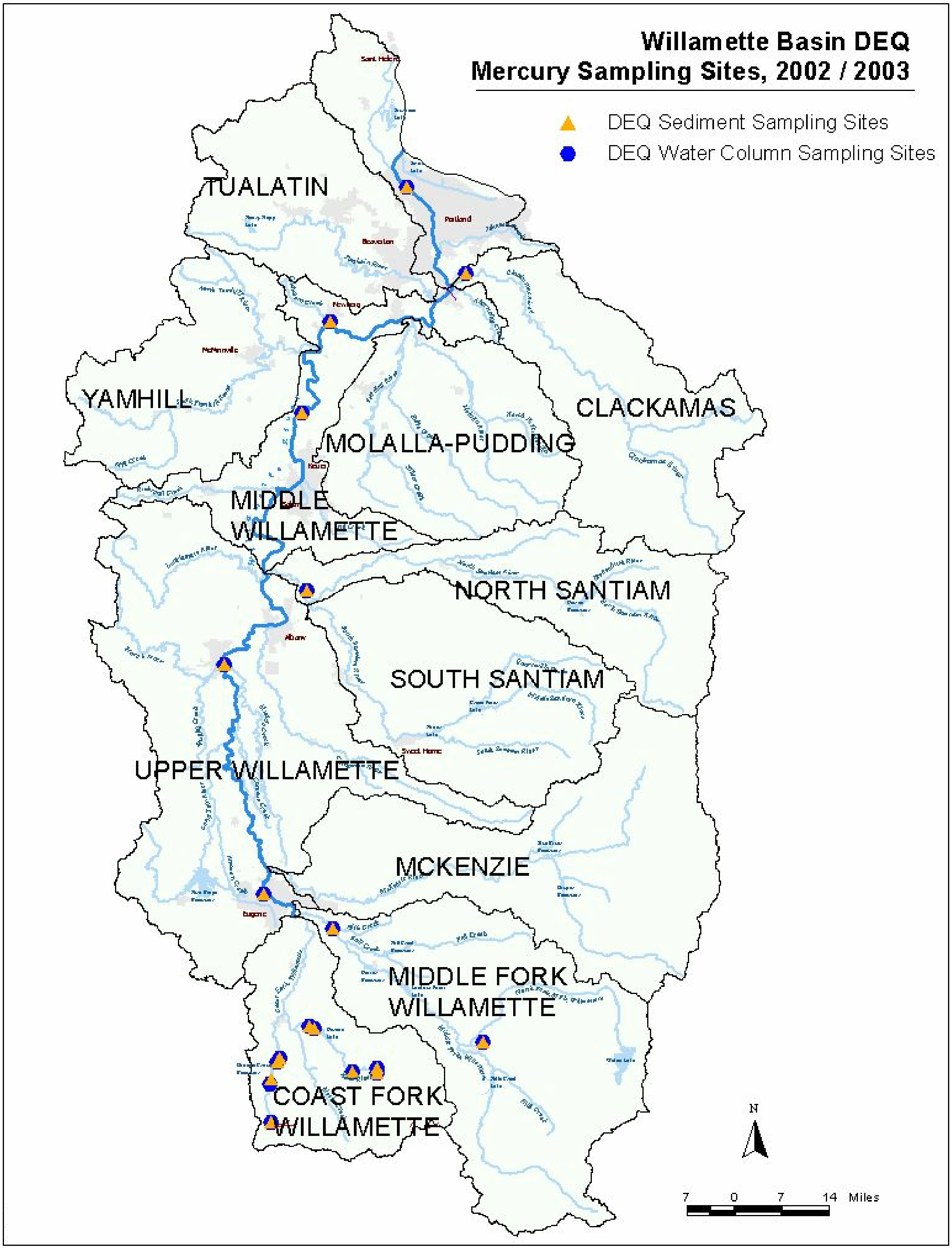


**Table 3. 2 Mercury Monitoring Sites in the Willamette Basin.**

| LASAR # | ID | Site Name | River Mile | LAT (DEC) | LON (DEC) | Water Samples | Fish tissue samples | Sediment Samples |
|---|---|---|---|---|---|---|---|---|
| 10332 | 1 | Willamette River (lower) – SP&S RR Bridge, Portland[(a)] | 7.0 | 45.5779 | -122.7475 | 4X/year | 1X/study | 1X/study |
| 26339 | 2 | Willamette River (Newberg Pool) – Rogers Landing | 50.1 | 45.2857 | -122.9658 | 4X/year | 1X/study | 1X/study |
| 10344 | 3 | Willamette River (middle) – u/s of Wheatland Ferry | 71.9 | 45.0906 | -123.0443 | 4X/year | 1X/study | 1X/study |
| 29043 | 4 | Willamette River (upper) – Willamette Park, Corvallis | 132.9 | 44.5518 | -123.2519 | 4X/year | 1X/study | 1X/study |
| 29044 | 5 | Willamette River (upper) – at Greenway Footbridge[(b)] | 180.0 | 44.0674 | -123.1119 | 4X/year | 1X/study | 1X/study |
| 29045 | 6 | Clackamas River - at Riverside Park | 3.2 | 45.3961 | -122.5618 | 4X/year | | 1X/study |
| 10775 | 7 | Santiam River at Jefferson | 9.7 | 44.7154 | -123.0129 | 4X/year | | 1X/study |
| 10386 | 8 | Middle Fork Willamette – at Jasper | 8.0 | 43.9982 | -122.9053 | 4X/year | | |
| 28614 | 9 | Coast Fork above Cottage Grove Res. – Raisor Rd | 32.5 | 43.6638 | -123.0778 | 4X/year | | 1X/study |
| 11278 | 10 | Coast Fork below Cottage Grove Res. | 29.5 | 43.7180 | -123.0490 | 4X/year | | 1X/study |
| 13750 | 11 | Cottage Grove Reservoir | | 43.7114 | -123.0556 | 4X/year | 1X/study | 1X/study |
| 10993 | 12 | Row River above Dorena Reservoir- at Sharps Crk Rd | 16.9 | 43.6959 | -122.8369 | 4X/year | | 1X/study |
| 10991 | 13 | Row River below Dorena Reservoir–at Government Rd | 6.7 | 43.7891 | -122.9675 | 4X/year | | 1X/study |
| 13769 | 14 | Dorena Reservoir | | 43.7833 | -122.9500 | 4X/year | 1X/study | 1X/study |
| 29047 | 15 | Dennis Creek (downstream of Black Butte mine) | 0.1 | 43.5816 | -123.0713 | 4X/year | | 1X/study |
| 29048 | 16 | Brice Creek (downstream of Bohemia Mining Dist.) – at RM 0.75 | .8 | 43.6940 | -122.7620 | 4X/year | | 1X/study |
| 29049 | 17 | Layng Creek (Background) – at RM 0.4 | .4 | 43.7045 | -122.7634 | 4X/year | | 1X/study |
| 27986 | 18 | Middle Fork Willamette above Hills Creek (Bkg.) – at USGS Gage | 52.9 | 43.7639 | -122.4550 | 4X/year | | 1X/study |
| 29232 | 19 | Middle Fork Willamette at Springfield Wellfield[(c)] | 1.9 | 44.0280 | -122.9828 | | | 1X/study |

(a) Due to the depth and difficulty of collecting fish at this particular site, additional fish were collected at the ‘Willamette River at Willamette Park, Portland’ site to complete the complement of fish from the Lower Willamette reach.

(b) Fish were collected at the ‘Willamette River upstream of McKenzie River and below Beltline Drive’ site in lieu of this site due to the fact that ODEQ could not get the fish shocking boat to this particular site.

(c) This site was just sampled once for sediment.

# WILLAMETTE MERCURY TMDL

## Sensitive Beneficial Use Identification

According to Oregon Administrative Rules (OAR) 340-041-0340, water quality in the Willamette Basin must be managed to protect a range of beneficial uses including fishing (see Table 340A; November 2003). The beneficial use of fishing applies to the entire mainstem Willamette River and its tributaries. The multiple fish consumption advisories issued for the Willamette Basin by the DHS indicate that this beneficial use is not currently being attained. The TMDL for mercury is designed to restore the beneficial use of fishing to the Willamette River and its tributaries.

Fish consumption advisories for mercury are currently in place for the Dorena (DHS, 2004a) and Cottage Grove Reservoirs (DHS, 2004b) as well as the entire mainstem Willamette River and the Coast Fork Willamette up to the Cottage Grove Reservoir (DHS, 1997a). The initial fish consumption advisory for the mainstem Willamette River, dated February 13, 1997, advised the public of elevated mercury levels in the edible fish tissue of bass and northern pikeminnow (squawfish) and recommended specific limits for consumers who eat these fish caught anywhere in the mainstem river system (from the mouth of the river upstream to the Cottage Grove Reservoir). The average level of mercury found in bass and northern pikeminnow was 0.63 mg/kg. The DHS issues fish consumption advisories when average mercury levels reach or exceed 0.35 mg/kg in edible tissue (see Appendix B for a description of the DHS methodology for issuing fish consumption advisories for mercury). The multiple fish consumption advisories for mercury led to a total of ten listings for mercury on the State's 2002 303(d) list of impaired waterbodies. It should be noted that in November, 2001 the DHS issued a 'consolidated' advisory for the Willamette River advising that *all species* of resident fish in the mainstem of the Willamette River should be eaten in only moderate amounts (DHS, 2001). This consolidated listing also considered pollutants other than mercury.

## Water Quality Standard Identification

ODEQ recently proposed a fish tissue methyl mercury criterion of 0.3 mg/kg in lieu of establishing specific water column criteria that are protective of 'water and fish ingestion' or 'fish consumption' only (ODEQ, 2003b). This proposed criterion was approved by Oregon's Environmental Quality Commission in May, 2004 and was submitted to the USEPA for approval. The overwhelming majority (>90%) of the mercury found in fish tissue is in the methylated form (Ullrich et al., 2001). The average fish tissue concentration for mercury in a number of fish species in the Willamette Basin currently exceeds the 0.3 mg/kg criterion. The current freshwater 'acute' criterion for mercury is 2.4 micrograms/liter and the freshwater 'chronic' criterion is 0.012 micrograms/liter (as presented in the Table 33A Water Quality Criteria Summary; OAR 340-041-0033). It is important to note that the Willamette River currently attains the current numeric criteria for the protection of aquatic life. The average annual concentration of mercury in the mainstem Willamette is approximately 1.3 ng/l (or 0.0013 micrograms/liter; see below).

In addition to the OARs pertaining to the maintenance of sensitive beneficial uses, there are also narrative standards that apply to the release of toxic chemicals in the Willamette Basin. The applicable standards presented below have been excerpted from OAR 340-041-0033.

*(1) Toxic substances may not be introduced above natural background levels in waters of the state in amounts, concentrations, or combinations that may be harmful, may chemically change to harmful forms in the environment, or may accumulate in sediments or bioaccumulate in aquatic life or wildlife to levels that adversely affect public health, safety, or welfare or aquatic life, wildlife, or other designated beneficial uses.*

*(2) Levels of toxic substances in waters of the state may not exceed the applicable criteria listed in Tables 20, 33A, and 33B. Tables 33A and 33B, adopted on May 20, 2004, update Table 20 as described in this section.*

*(a) Each value for criteria in Table 20 is effective until the corresponding value in Tables 33A or 33B becomes effective.*

*(A) Each value in Table 33A is effective on February 15, 2005, unless EPA has disapproved the value before that date. If a value is subsequently disapproved, any corresponding value in Table 20 becomes effective immediately. Values that are the same in Tables 20 and 33A remain in effect.*

[Note that to date, the USEPA has neither approved nor disapproved Oregon's revised toxics criteria.]

*(B) Each value in Table 33B is effective upon EPA approval.*

*(b) The department will note the effective date for each value in Tables 20, 33A, and 33B as described in this section.*

*(3) To establish permit or other regulatory limits for toxic substances for which criteria are not included in Tables 20, 33A, or 33B, the department may use the guidance values in Table 33C, public health advisories, and other published scientific literature. The department may also require or conduct bio-assessment studies to monitor the toxicity to aquatic life of complex effluents, other suspected discharges, or chemical substances without numeric criteria.*

## Pollutant and Target Identification

This TMDL focuses on the bioaccumulation of mercury in edible fish tissue. As stated before, mercury may be present in various physical and chemical forms in the environment (Ullrich *et al.,* 2001; USEPA, 2001b). The form of mercury most prone to bioaccumulation, however, is methyl mercury (USEPA, 2001a). Unfortunately, methyl mercury monitoring is quite expensive and difficult due to the ultra-clean sampling procedures and sophisticated laboratory equipment required to quantify the extremely low concentrations found in Willamette River water and sediment. Due in part to these practical limitations, there were limited methyl mercury data available from the Willamette River, its tributaries, and the various mercury sources present in the Willamette Basin prior to this study.

The interim guidance values developed in this study represent numeric targets that are protective of the beneficial use of fish consumption. In essence, the TMDL is calculating the concentration of mercury in water that will not bioaccumulate in aquatic life or wildlife to levels that adversely affect public health, safety, or welfare. The interim guidance values established in this TMDL are *not* considered to be site-specific numeric criteria (standards) but rather system-wide average annual concentrations that will allow us to restore the beneficial use of fish consumption and the protection of public health. All proposed changes to the water quality standards (including the establishment of site-specific numeric criteria) must go through a separate public review process and, ultimately, submittal to USEPA for approval before a change can take place.

In interpreting the narrative standard, ODEQ does not expect each and every source of mercury to discharge below the interim guidance values established in this TMDL. The goal of this TMDL is to implement broad, cross-sector mercury reductions which will eventually bring water column concentrations of mercury in the Willamette Basin down to the guidance values. If this goal were to be achieved in the Willamette, then, according to our analysis, the beneficial use of fish consumption would eventually be restored. ODEQ commits to the continued monitoring and analysis for mercury as part of the iterative adaptive management framework. It is likely that the interim guidance values presented in this TMDL will change as more data and information are incorporated into the analysis.

The focus of this TMDL effort has been on addressing the multiple 303(d) listings pertaining to the human health fish consumption advisories for mercury. If, at some point in the future, the Willamette Basin is listed on the State's 303(d) list for water quality limitations and/or beneficial use impairments associated with ecological or other endpoints, then the TMDL will be revisited with the goal of addressing these additional concerns.

This TMDL establishes interim guidance values and allocations based on units of *total* mercury, as opposed to methyl mercury. The decision to develop guidance values based on units of total mercury was necessitated by the paucity of ambient and source-specific methyl mercury data, the expense and difficulty associated with low-level methyl mercury analysis, and the fact that significant methyl mercury bioaccumulation has been observed at concentrations at or near the method detection limit. Whereas methyl mercury is the form of mercury most prone to bioaccumulation, establishing guidance values in units of total mercury allows us to utilize the more readily available total mercury data to provide information on source loading, relative contributions, and to monitor the effectiveness of control strategies. This approach is consistent with USEPA guidance on the implementation of the methyl mercury water q+uality criterion (USEPA, 2001b).

There are several ways to develop a translator. ODEQ chose to use an empirical method to develop a translator which was consistent with established methods and the available data set. Ambient monitoring data gathered over the course of this study allowed us to empirically estimate the relative ratio (as a percentage) of dissolved methyl mercury (DMeHg) to total mercury (THg) in the water column of the Willamette River. This DMeHg:THg translator (also known as omega) was used to establish water column guidance values based on units of total mercury, recognizing that it is the methylated form of mercury that is actually prone to bioaccumulation. ODEQ acknowledges that a translator determined in this manner reflects only observed conditions and not what is theoretically occurring in the watershed and does not shed any light on underlying mechanisms of methylmercury production or cycling or the linearity or non-linearity of the total mercury - methylmercury relationship.

*Translator (Omega) = Dissolved Methyl mercury (DMeHg) : Total Mercury (THg)*

The estimate of this translator was based on empirical data from the Willamette Basin mercury study. Data from four quarterly sampling events (as presented in Appendix B) were used to develop the estimate of the average annual translator value used in this TMDL analysis. Seasonal variations caused the cumulative translator distributions to shift as samples from each quarter were added to the dataset (as demonstrated in Figure 3.1). The distribution of site-specific translator ratios from the Willamette Basin mercury study presented in Figure 3.2 represents the cumulative dataset from four quarters of sampling. The median of the distribution of translator values from all four quarters is 0.03, the mean is 0.05 and the 90$^{th}$ percentile range is 0.01-0.18 (see Figures 3.1 and 3.2). In other words, on an average annual basis, approximately five percent of the total mercury measured in the water column is found in the methylated form.

It is important to note that these empirically-derived site-specific translator values from the Willamette (presented in Figures 3.1 and 3.2) are consistent with USEPA proposed default values especially those presented for lakes (USEPA, 2001b). Several explanations for the convergence of translator values with those for lakes and reservoirs are possible: (1) coincidence, (2) data from reservoirs, tributaries, and the mainstem Willamette River were combined to make this estimate, obscuring the effects of flowing water, or (3) the mainstem Willamette, because of its size and regulation, behaves more like a large, slow lake than a fast moving river.

**Figure 3.1 Cumulative Translator (Omega) Distributions from the Willamette Basin Mercury Study**

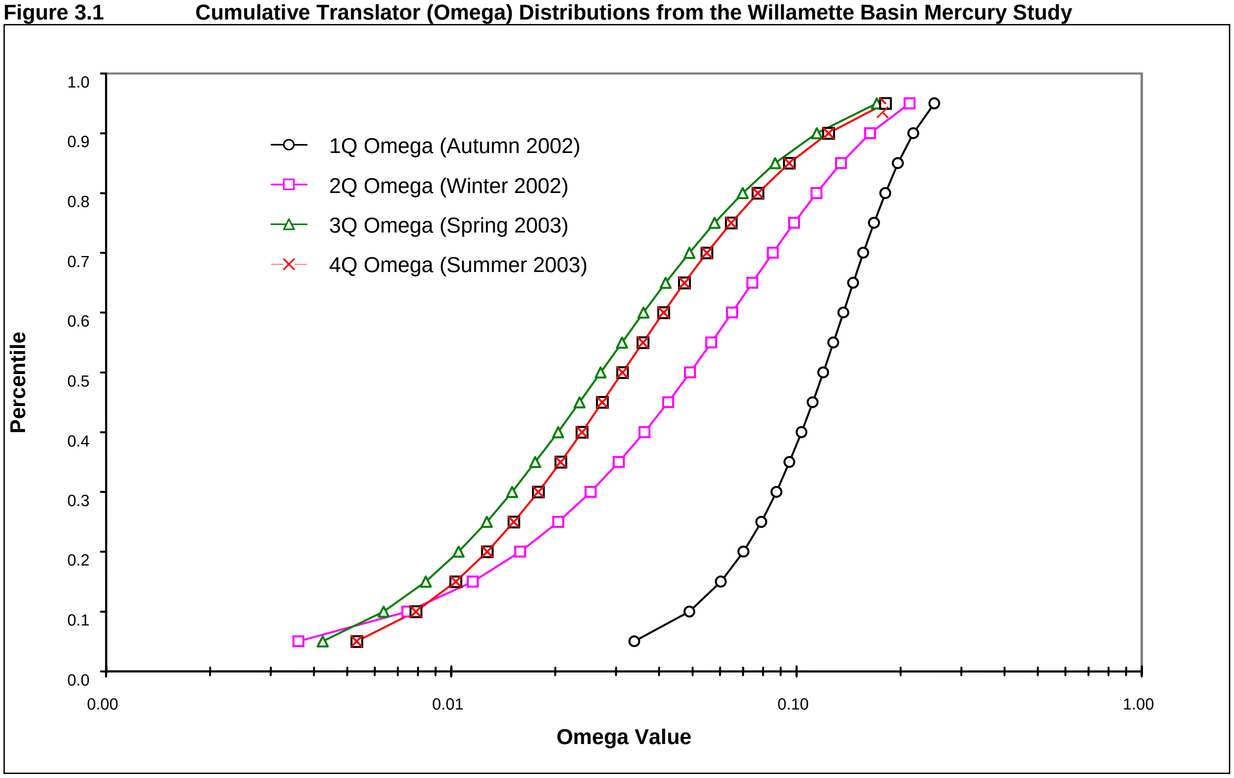
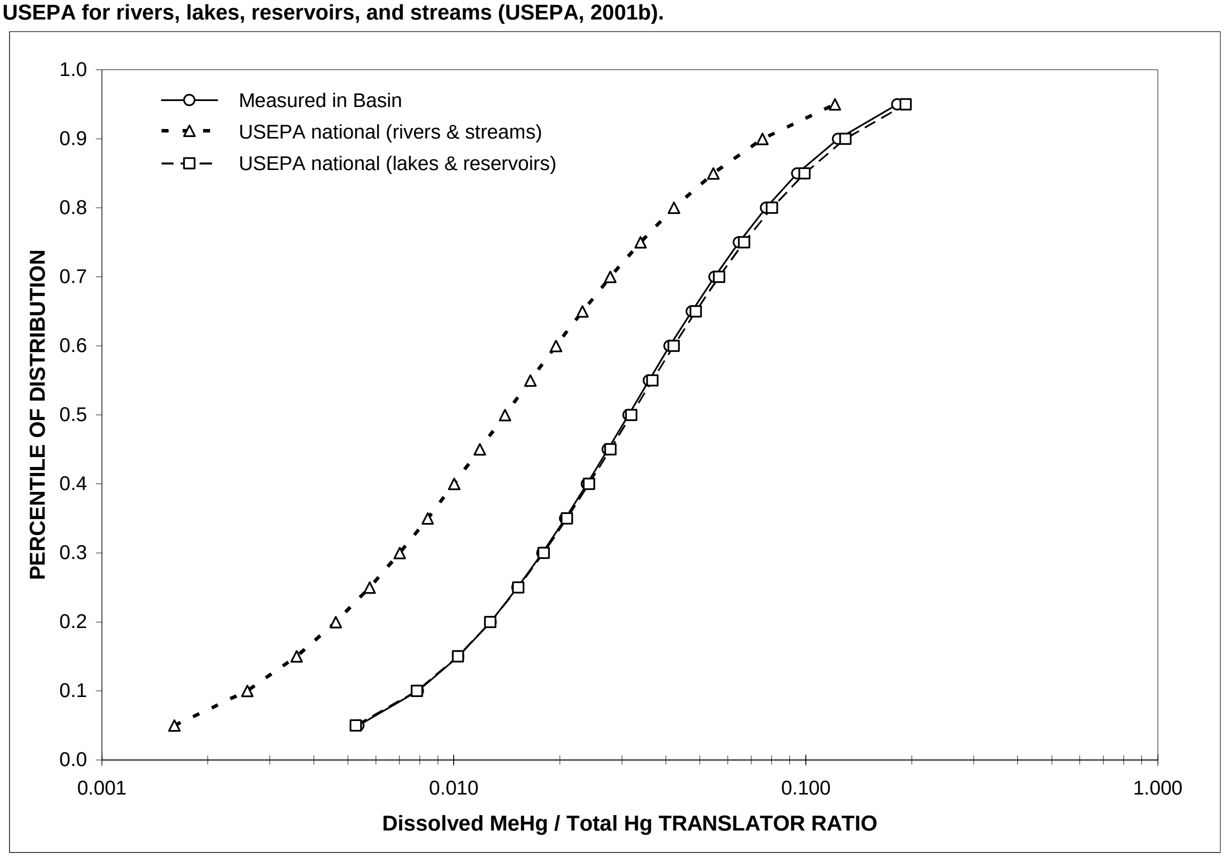



**Figure 3.2 Comparison of MeHg - THg translator ratios measured in the Willamette Basin to ratios estimated by the USEPA for rivers, lakes, reservoirs, and streams (USEPA, 2001b).**



Interim guidance values are presented in units of total mercury for each of the fish species considered in the model (Table 3.3). The FWM calculates a range of water column guidance values for each fish species considered varying in their degree of protectiveness for human consumers. There are three guidance values presented in Table 3.3 for each of the resident fish species considered in the FWM. These three values correspond to the 5$^{th}$, 50$^{th}$ and 95$^{th}$ percentiles. At the median level (the 50$^{th}$ percentile) there is a fifty percent likelihood that a given fish species would have a fish tissue concentration at or below the USEPA fish tissue criterion for methyl mercury (0.3 ppm). Interim guidance values for selected fish species are also presented in units of dissolved methyl mercury (Table 3.4).

As mentioned before, the methodology for establishing water column guidance values in units of total mercury, as opposed to methyl mercury, is consistent with guidance from USEPA (USEPA, 2001b). One of the basic assumptions inherent in the methodology presented by USEPA (and utilized in this TMDL) is that there is a direct association between the loading of total mercury to waters of the Willamette and the formation of methyl mercury. As more total mercury, bound to sediments and organic matter, enters the Willamette, more methyl mercury can eventually be produced by bacteria. The validity of this assumption will be addressed by future studies as a component of the adaptive management process.

**Table 3. 3 Interim Species-Specific Water Column Guidance Values for Total Mercury in the Willamette Basin, Based on a Post-Calibration Model**

| Fish Species | Model Estimate (ng/L) [a] | | |
|---|---|---|---|
| | 5$^{th}$-%tile [b] | 50$^{th}$-%tile [c] | 95$^{th}$-%tile [d] |
| Northern pikeminnow | 10.03 | 0.92 | 0.07 |
| Largemouth bass | 15.16 | 1.27 | 0.11 |
| Smallmouth bass | 38.42 | 2.82 | 0.20 |
| Rainbow trout | 54.72 | 4.78 | 0.31 |
| Bluegill | 37.56 | 3.65 | 0.40 |
| Largescale sucker | 28.97 | 2.75 | 0.22 |
| Carp | 34.96 | 3.25 | 0.21 |
| Cutthroat trout | 73.40 | 6.02 | 0.50 |

a) Calculated using Equation {12} and 1-D MC methods (see Appendix B), with biomagnification factor and $\Omega$ as distributions.
b) Total mercury concentration that would achieve the USEPA tissue criterion in 5 percent of individuals.
c) Total mercury concentration that would achieve the USEPA tissue criterion in 50 percent of individuals.
d) Total mercury concentration that would achieve the USEPA tissue criterion in 95 percent of individuals.

**Table 3. 4 Interim Water Column Guidance Values for Dissolved Methyl Mercury for Selected Fish Species in the Willamette Basin, Based on a Post-Calibration Model**

| Fish Species | Model Estimate (ng/L) [a] | | |
|---|---|---|---|
| | 5$^{th}$-%tile [b] | 50$^{th}$-%tile [c] | 95$^{th}$-%tile [d] |
| Northern pikeminnow | 0.137 | 0.029 | < 0.02 |
| Largemouth bass | 0.200 | 0.037 | < 0.02 |
| Smallmouth bass | 0.614 | 0.087 | < 0.02 |

a) Calculated using Equation {12} and 1-D MC methods (see Appendix B)
b) Dissolved methyl mercury concentration that would achieve the USEPA tissue criterion in 5 percent of individuals.
c) Dissolved methyl mercury concentration that would achieve the USEPA tissue criterion in 50 percent of individuals.
d) Dissolved methyl mercury concentration that would achieve the USEPA tissue criterion in 95 percent of individuals.

Confidence in estimates of water column guidance values is moderate due to limitations imposed by characterizing a large watershed with limited data. The choice of translator value, representing the percentage of total mercury in the methylated form, can influence the development of water column guidance values. After four sampling events, the translator values stabilized at a mean of approximately 5%. The range of ambient methyl mercury concentrations used in the FWM represents another critical variable with the potential to influence the development of water column guidance values. Methyl mercury concentrations, however, fluctuated to a significantly lesser extent than total (unfiltered) mercury concentrations and remained essentially constant throughout the year. The current estimates of both the translator value and the range of ambient methyl mercury concentrations in the mainstem Willamette are based on quarterly sampling data from a single year. Additional ambient monitoring over the course of the next three years will help establish better long-term estimates of the translator value and ambient conditions in the Basin. This new information will allow us to refine our estimates of the appropriate water column guidance values and the necessary percent reductions as a component of the iterative adaptive management framework. The policy decision to pursue the interim approach outlined in this TMDL was based in part on significant input from members of the Willamette Basin TMDLs Council.

## Estimates of Mercury Mass Loads and Sources

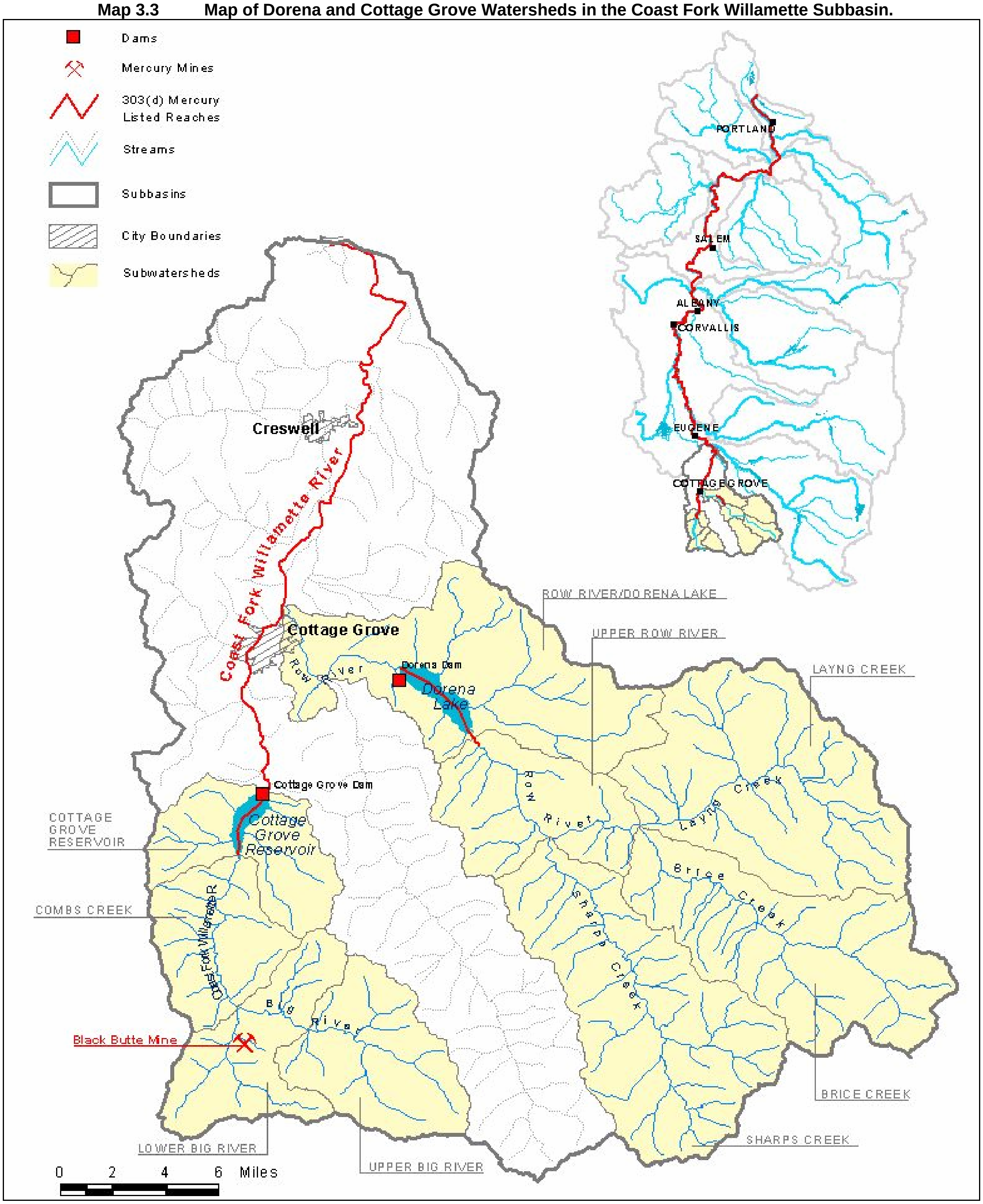
### *Data Review and Analysis*

The TMDL for mercury is required to evaluate, to the extent existing data allow, the difference between the actual pollutant load in a waterbody and the loading capacity of that waterbody. The loading capacity for this analysis is defined as the load of total mercury (estimated in kg/yr) associated with the interim water column guidance value. The water column guidance value represents the mercury concentration in water that is correlated with an acceptable fish tissue criterion (as predicted by the Food Web Model). Attainment of this water column guidance value should, over time, allow for the restoration of the beneficial use of fish consumption.

The TMDL must also identify the various sources of the pollutant and estimate, to the extent existing data allow, the amount of actual pollutant loading from each of these sources. These estimates of mercury mass loads and sources in the Willamette Basin have been conducted and are presented in Appendix B. It should be noted that the effort to estimate mercury mass loads and sources in the Willamette Basin has been an iterative process with significant stakeholder involvement and discussion via the Willamette River TMDLs Council.

The data reviewed and generated by ODEQ support conducting a *system-wide* TMDL for mercury in the mainstem Willamette River system and then separate subbasin-level analyses for the Cottage Grove and Dorena watersheds (Map 3.3). These two watersheds in the Coast Fork Willamette Subbasin are downstream of areas known to be associated with mercury mining and mercury use in gold and silver amalgamation. The Black Butte abandoned mine site, located in the headwaters of the Coast Fork Willamette River above the Cottage Grove Reservoir, represents a likely source of mercury to downstream waterbodies particularly the Cottage Grove Reservoir. The Black Butte abandoned mine site is characterized by exposed tailing piles and elevated mercury concentrations in soils resulting from an inefficient mercury extraction and recovery processes. Mercury was used historically in the Bohemia Mining District (along Sharps and Brice Creeks upstream of the Dorena Reservoir) to enhance the recovery of gold. This historical use of mercury represents an additional legacy mining source with the potential to impact downstream waterbodies. These downstream impacts are most likely to be observed in the reservoirs immediately below the legacy mining areas since the reservoirs represent barriers to the transport of particle-bound mercury to the lower watershed and most likely create conditions favorable for the production of methyl mercury. Therefore, separate analyses have been conducted to determine the mass loading and relative source contributions in each of these two watersheds (Appendix B). Whereas legacy mining sources appear to represent relatively minor sources of mercury to the mainstem Willamette River system and the Dorena Reservoir, these sources have the potential to significantly impact the Cottage Grove Reservoir. The entire Coast Fork Willamette Subbasin has still been considered in the mainstem mercury analysis as a potential input of mercury.

**Map 3.3 Map of Dorena and Cottage Grove Watersheds in the Coast Fork Willamette Subbasin.**



Still there are many unknowns about mercury loads and sources in the Willamette Basin due to the sheer scale of the area considered, the seasonal variation in mercury concentrations, and the limited dataset available particularly pertaining to source load contributions. This TMDL attempts to utilize the information available while acknowledging the various data gaps that still exist. The intent in developing interim guidance values and allocations is to provide information supporting the interpretation of the numeric and narrative standards and to guide the development of future studies (monitoring and analysis) that will provide useful information and additional data on mercury loads and sources. This new information will help us further refine the guidance values and the allocations established in this TMDL as part of the adaptive management process (see below).

### *Mercury Mass Loads*

The estimated mass of total mercury discharged from the Basin as fluvial load was estimated as a function of river flow rate at the confluence (river mile 0) and mercury concentration in unfiltered surface water samples. USGS flow data were available from five gauging stations along the mainstem of the Willamette River (USGS, 2003). An empirical relationship was developed between river flow rate and river mile by pairing measured daily mean flow rates with river mile. This relationship was then used to estimate the daily mean flow rate at sampling locations along the mainstem where daily mean flow rate data were not available for the period between 1997 and 2003. During 2002 and 2003, ODEQ conducted quarterly mercury sampling at 18 sampling stations in the Willamette Basin (Map 3.2 and Table 3.2). ODEQ samples were analyzed using ultra-low detection methods (USEPA Method 1631E) and combined with those from periodic sampling performed by the Cities of Portland, Wilsonville, Corvallis, and Eugene between 1997 and 2003. An empirical relationship was then formed between daily mean flow at RM 0 and the concentration of total mercury in the mainstem. There is a moderate positive correlation between concentration and flow for total mercury; a correlation consistent with the seasonal mobilization of fine-grained particulates in the river sediment and runoff (erosion) with which mercury is associated.

The estimated average annual mass load of total (unfiltered) mercury was estimated at the confluence (RM 0) as a function of concentration and flow rate. The annual output from the Basin was thus defined as the mercury discharge rate in units of kg/yr at RM 0. An average of 126.8 kg of total mercury is estimated to be discharged by the Willamette into the Columbia River each year. The estimated inputs of mercury to the Basin (128.6 kg/yr; see Source Identification section below) slightly exceed the mercury mass leaving the Basin as fluvial load, suggesting that a portion of the mercury is deposited in the river bottom. An analogous process was employed to estimate the mass loading of mercury into the Dorena and Cottage Grove watersheds. Estimates of total mercury mass loads into the Dorena and Cottage Grove Reservoirs are 2.08 and 3.13 kg/yr, respectively.

### *Source Identification*

As described in Appendix B, a combination of available data and informed assumptions were used to identify and quantify the sources contributing to the mass load of total mercury in the Mainstem Willamette River and the Coast Fork tributaries. Source categories considered in this analysis include: atmospheric deposition (from both local and far-field sources); erosion of native soils; historical mining activity; sediment resuspension; and municipal and industrial water discharges. Data from ODEQ were combined with the available information from municipal and industrial sources to generate the estimates presented below. The various data sources and informed assumptions employed in the source characterization analyses are presented in detail in the technical appendix.

Limitations in the available dataset create hindrances to our understanding of the nature and extent of mercury loading from the various sources present in the Basin. For example, there is little Basin-specific information on the actual erosion rates of native soils from various land use categories. In this analysis, literature rates for soil erosion were utilized in lieu of actual monitoring data. There is also little information available on the actual mercury concentrations found in effluent and stack emissions from key industrial sectors. Default values from the USEPA and emission factors (for the air sources) were employed in the source characterization study to bridge this significant data gap. Estimates from industrial sectors were also considered. We have only recently begun to collect atmospheric deposition data within the Basin through the placement (by the USGS in 2003) of two atmospheric deposition collectors at its northern and southern ends. These collectors have become part of the National Atmospheric Deposition Program/Mercury Deposition Network (MDN). Data from MDN sites, as well as monitoring data from planned point source studies, will be incorporated into future iterations of this TMDL. The additional work outlined in the WQMP is absolutely essential for refining the preliminary source characterization estimates presented below.

A summary balance of mercury inputs and outputs for the mainstem Willamette River is presented in Table 3.5. A preliminary mass balance for mercury is achieved by matching the estimated Basin output (as fluvial load at RM 0) to the sum of the estimated Basin inputs (from the source characterization analysis). Air deposition supplies a total of 61.3 kg/yr to the river, of which 7.6 kg/yr comes from direct deposition to water, and 6.4, 10.0, 14.7, and 22.5 kg/yr result from runoff (overland flow) from urban, mixed, forest, and agricultural land, respectively. Erosion of native soil contributes an additional 61.4 kg/yr of mercury to the river. The total load from all nonpoint sources is 123.5 kg/yr. The estimated load from all known and currently quantified point sources is 5.0 kg/yr, for a total annual average input of 128.5 kg/yr to the river. Since annual average output (at the confluence of the river) is 126.8 kg/yr, achieving a mass balance requires the assumption that approximately 1.7 kg/yr is removed (on long-term average) from the water column through deposition on the river's bottom. Evidence suggests that significant depositional segments include the Newberg Pool and the lower Willamette River, the reach from below Willamette Falls to the confluence. It is estimated that the amount of mercury available for re-suspension will decrease over time as cross-sector measures to address mercury loading (described in detail in Chapter 14) are implemented.

**Table 3. 5 A Summary of the Adjusted Balance of Mercury Inputs and Outputs for the Mainstem Willamette River System.**

| Description of Input or Output | Report Section (see Appendix B) | Annual Mean Rate (kg/yr) | Percent Contribution of total load (128.5 kg/yr) |
|---|---|---|---|
| **Average annual cumulative output** | 2.0 | 126.8 | |
| **Average annual inputs** | | | |
| ***Nonpoint Sources*** | | | |
| Runoff of atmospherically deposited mercury | 3.1 | 53.7[(a)] | 41.8 |
| Direct deposition to open water | 3.1 | 7.6 | 5.9 |
| Erosion of mercury containing soils | 3.2 | 61.4[(a)] | 47.8 |
| Legacy mine discharges | 3.4 | 0.8[(b)] | 0.6 |
| Sediment re-suspension (input to water column) | 3.8 | 0.0 [(c)] | 0.0 |
| ***Point Sources*** | | | |
| POTW Discharges | 3.5 | 3.5 | 2.7 |
| Industrial Discharges | 3.6 | 1.5 | 1.2 |
| **Total Inputs** | | 128.5 | 100 |
| Sediment Deposition (output from water column) | | -1.7 [(d)] | |

(a) The estimate of the total mercury load for this source category includes a component attributable to stormwater discharges from urbanized areas. These stormwater inputs may originate in either Municipal Separate Storm Sewer System (MS4) communities or non-MS4 communities and includes the overland flow of mercury directly into impacted waterbodies. In certain situations these loadings may be considered to be point sources, as in the case of MS4 discharges, but for the purpose of this analysis, the stormwater component is contained within the 'runoff of atmospherically deposited mercury' and 'erosion of mercury containing soils' categories and is accounted for here as a nonpoint source category.

(b) The contribution from legacy mines is considered to be a nonpoint source input due to the reasons outlined in the text of this document.

(c) Seasonal average value, expected to be significantly higher during the wet (high flow) season.

(d) Estimated indirectly as Output minus Total Inputs (126.8 - 128.5 = -1.7). Seasonal average value, expected to be zero during the wet (high flow) season.

Annual mean estimates of the relative source load contributions for the mainstem Willamette River are presented in Figures 3.3 and 3.4. These figures show the relative contributions of the various inputs of mercury to the total inputs, based on the values presented in Table 3.5. The load associated with the erosion of native mercury-containing soils (47.8%) and the runoff of atmospherically-deposited mercury from local and global sources (47.7%) represent the two largest mercury inputs to the mainstem Willamette River system. These two source categories include a component attributable to stormwater discharges from urbanized areas from both Municipal Separate Storm Sewer System (MS4) communities and non-MS4 communities. The runoff of atmospherically-deposited mercury from urban environments was estimated at 5% of the total load. It was not possible at this time to further quantify the load of mercury attributable to stormwater discharges from urbanized environments due to a lack of site-specific data and information from the scientific literature. The stormwater inputs, however, are fully accounted for in the estimates of the loads associated with air deposition from local and global sources and native soil erosion.

The estimated average input from the municipal point sources is, at 2.7%, a relatively small contribution to the total input. Similarly, the estimated contribution from the Industrial (Pulp and Paper) Sector is 1.5 kg/yr or the equivalent of 1.2% of the total load.

The annual mean estimates presented in Table 3.5 and Figures 3.3 and 3.4 obscure the significant seasonal fluctuations in both the magnitude and source of mercury inputs. For example, seasonal variation in precipitation and snow melt can affect: flow rate, which determines whether sediment is re-suspended or deposited; wet deposition, which affects air inputs to land; and surface runoff and erosion, which together affect outputs from land to water. The estimated relative source contributions during winter (high flow) events are presented in Figure 3.5. The estimated load associated with sediment resuspension increases significantly during these periods of high winter flows.

Annual mean estimates of the relative source load contributions for the Cottage Grove and Dorena watersheds are presented in Figures 3.6 and 3.7, respectively. Whereas legacy mining represents a significant source of mercury in the Cottage Grove watershed, it does not appear to be a major source of mercury in the Dorena system. (It should be noted that whereas mercury was mined commercially in the Cottage Grove watershed, there are no known mercury mines in the Dorena system.) The analysis for the Dorena watershed was limited by a paucity of monitoring data (when compared to the Cottage Grove analysis) and less information on flow. It is possible that future analysis will demonstrate more of a legacy mining component in this particular watershed due to the historical use of mercury in gold amalgamation in the Bohemia Mining District.

The legacy mine contributions are considered as nonpoint source inputs in this TMDL analysis for the following reasons.

- Elemental mercury was used throughout the Bohemia mining district to amalgamate gold. The mercury contamination resulting from these past practices is diffuse in nature with the potential for trace levels of mercury to be found in river sediments throughout the Bohemia region, particularly along Brice Creek, the primary watershed within the Bohemia mining district. Hygelund et al. (2001) report that river sediment samples from many locations along Brice Creek contain mercury at concentrations in the range of 0.1 – 1.4 parts per million.
- Studies suggest that there may be diffuse mercury contamination at the abandoned Black Butte Mine due in part to the volatilization and subsequent deposition of mercury around the furnace areas where mercury-containing rock was cooked and crushed (Curtis, 2004). Surface soil samples taken from around the site contain mercury at elevated concentrations with concentrations highest in areas around historic furnace locations.
- There does not appear to be significant acid mine drainage or adit discharges of mercury at the Black Butte abandoned mine site (ODEQ, 2004).
- ODEQ is relying on state and federal environmental cleanup laws as the lead authority for the investigation and remediation of the Black Butte abandoned mine site.

ODEQ is not able at this time to further distinguish the contribution of mercury from individual sources within the legacy mining areas in the Coast Fork Willamette watershed due to a lack of data. ODEQ recently received an award consisting of USEPA contractor assistance worth an estimated $60K for the next phase of the Black Butte cleanup. The sampling and analysis work planned at Black Butte will help characterize the nature and extent of contamination in the on-site tailings and mine workings in the immediate vicinity of the furnaces. ODEQ is also beginning to work with USEPA's Site Assessment Program on an initial assessment of the Row River watershed, above Dorena Reservoir. This study will help estimate the extent to which historic mine sites located in the Bohemia mining district may be contributing to elevated levels of mercury in the Willamette basin. As these efforts proceed and as our understanding of sources of mercury within these legacy mining areas evolve, every effort will be made to consider the substantive requirements of the Clean Water Act, as deemed appropriate.

An attempt was made in this preliminary phase of the mercury TMDL to differentiate between non-anthropogenic (natural, background) and anthropogenic sources of mercury, to the extent possible. Each of the categories considered in the mercury source characterization analysis may include mercury originating from natural sources although the precise quantification of this background component can be constrained by a paucity of literature values and site-specific information from the Willamette Basin. Mercury loading attributable to the erosion of native soils from agricultural and forested land is, for example, based entirely on the concentration of mercury naturally present in native soils. Erosion of native soil from undisturbed areas (attributed to natural sedimentation or the sloughing of stream banks) was not quantified as available data suggest it represents only a small percentage of total native soil erosion in the Basin (NRCS 1998, 2000). Monitoring data and published studies from the area around the abandoned mercury mine above Cottage Grove reservoir clearly indicate that soil mercury concentrations significantly exceed mercury concentrations in native soil (Morgans 2003, Park and Curtis, 1997). So, although a small percentage of the total load of mercury from this area may be due to naturally occurring mercury, it is clear that legacy mining activities at this site have resulted in diffuse mercury contamination over and above this natural background component. In terms of atmospheric deposition, an attempt was made to differentiate between contributions from local (largely anthropogenic point, area, and mobile) sources within the Basin and those from global sources (a mix of natural and anthropogenic mercury emissions) from beyond the Basin. The present analysis does not account for the volatilization (or recycling) of the mercury present in native soil or that which is deposited from the atmosphere. The current estimates of mercury loading from industrial and municipal point sources do not take into consideration the presence of naturally occurring mercury in the intake water of these point sources. Knowledge of these concentrations would help greatly in refining current estimates of mercury loads associated with domestic and industrial effluents. The work planned for the next phase of this mercury TMDL will enable a more precise accounting of natural background and the loads associated with each of the source categories considered in this analysis.

**Figure 3.3** **Relative Load Contributions for the Mainstem Willamette River System by Source Category (Total Load = 128.5 kg/yr).**

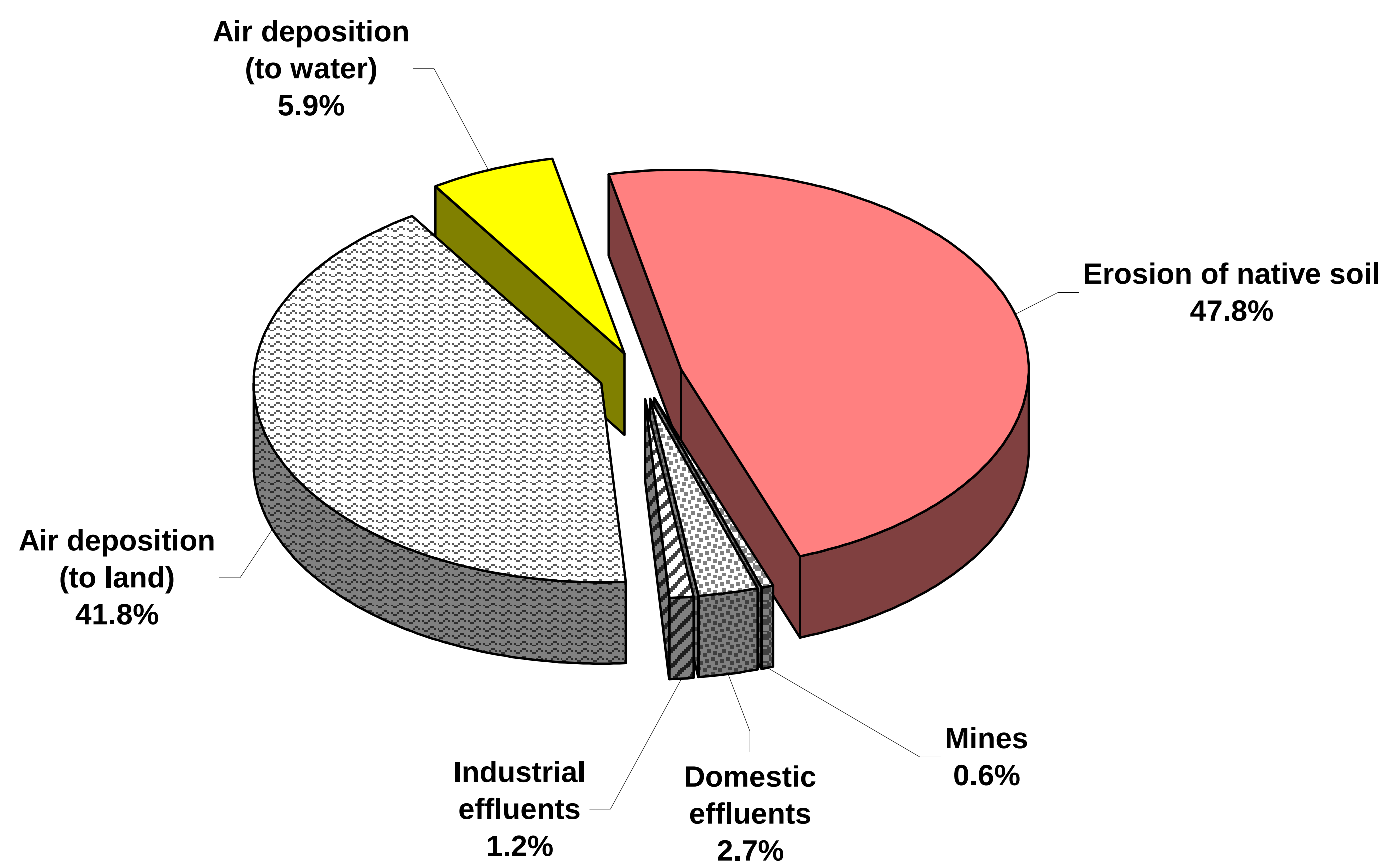


**Figure 3.4** **Relative Load Contributions for the Mainstem Willamette River System by Land Use Category (Total Load = 128.5 kg/yr).**

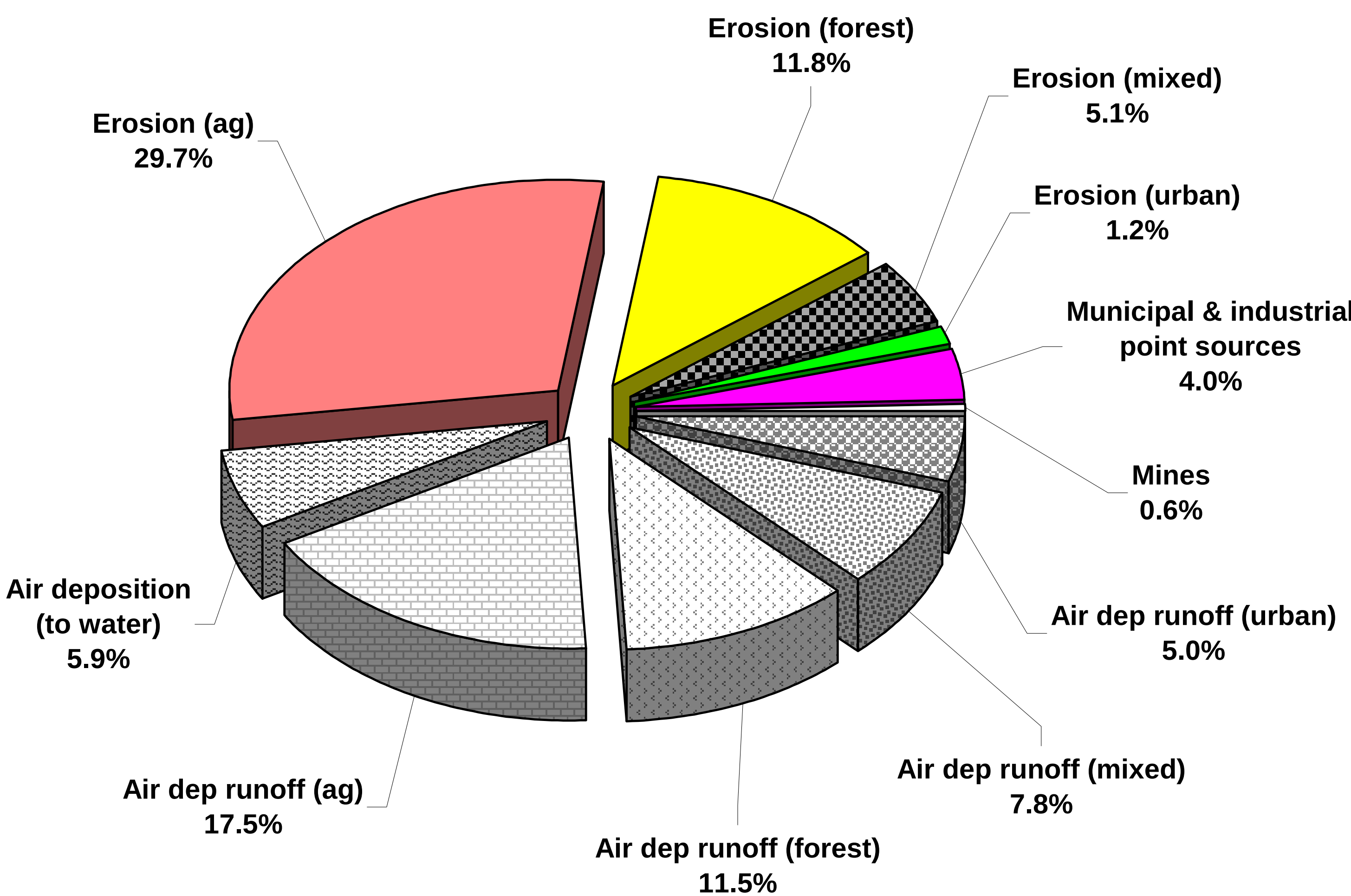


**Figure 3.5** **Relative Source Load Contributions for the Mainstem Willamette River System (Winter High Flow Estimate; Total Load = 416.6 kg/yr)**

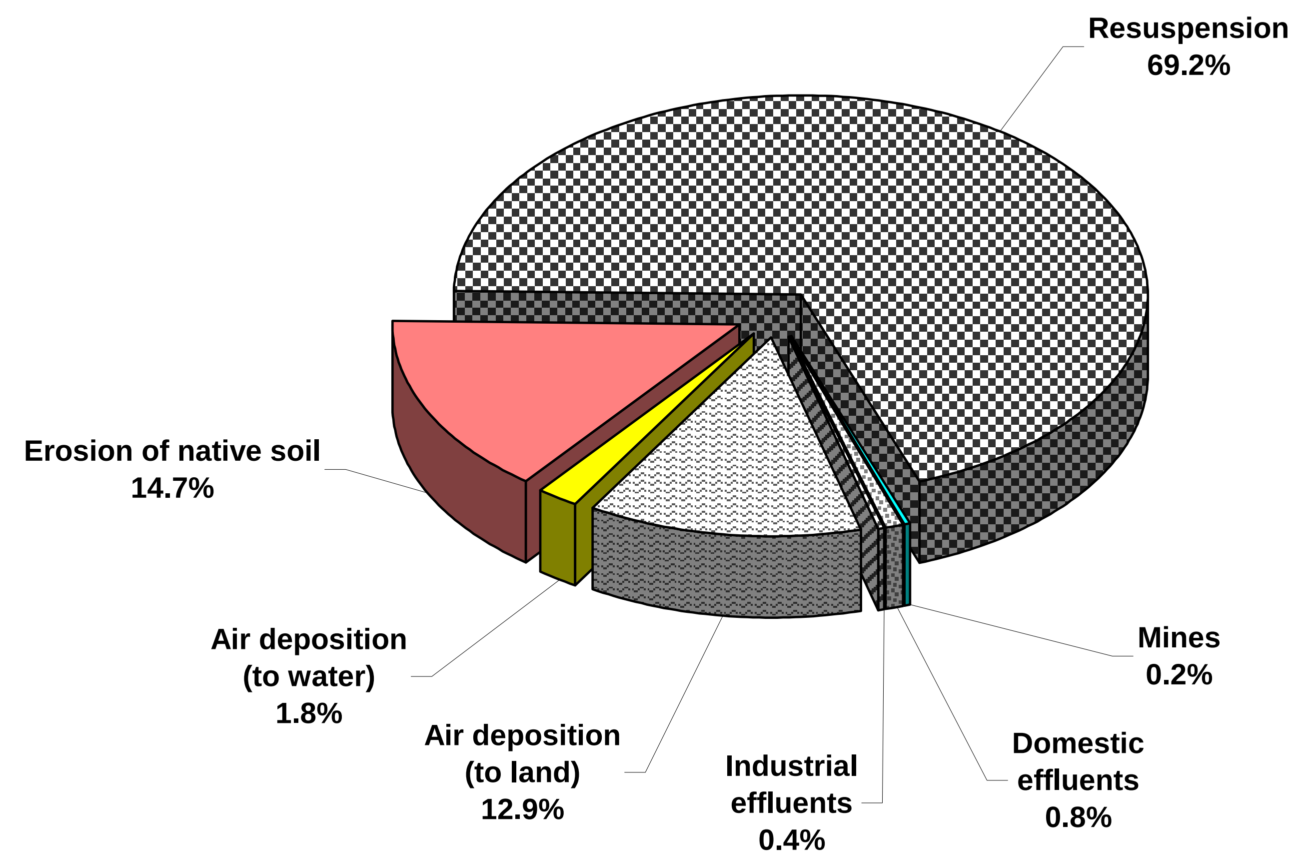


**Figure 3.6** **Relative Source Load Contributions for the Cottage Grove Watershed (Total Load = 3.13 kg/yr)**

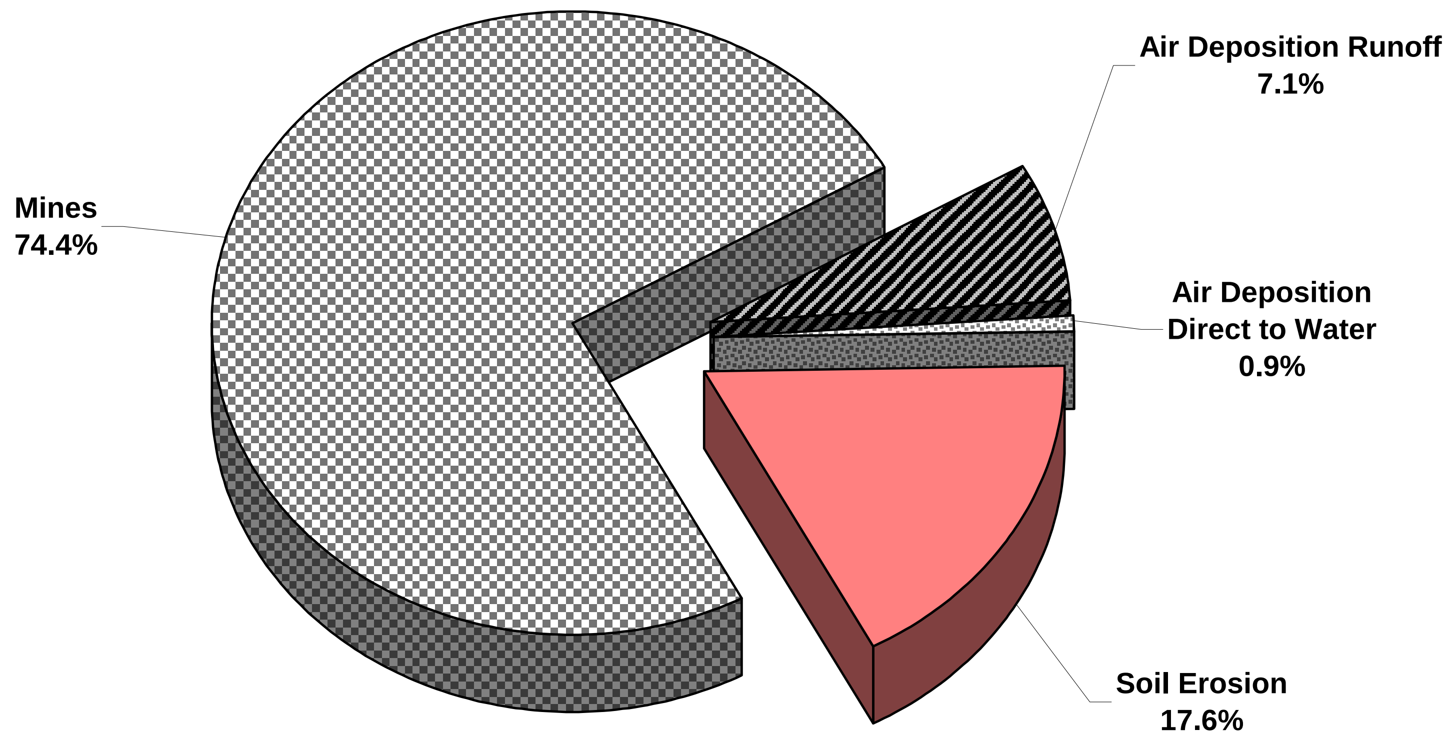
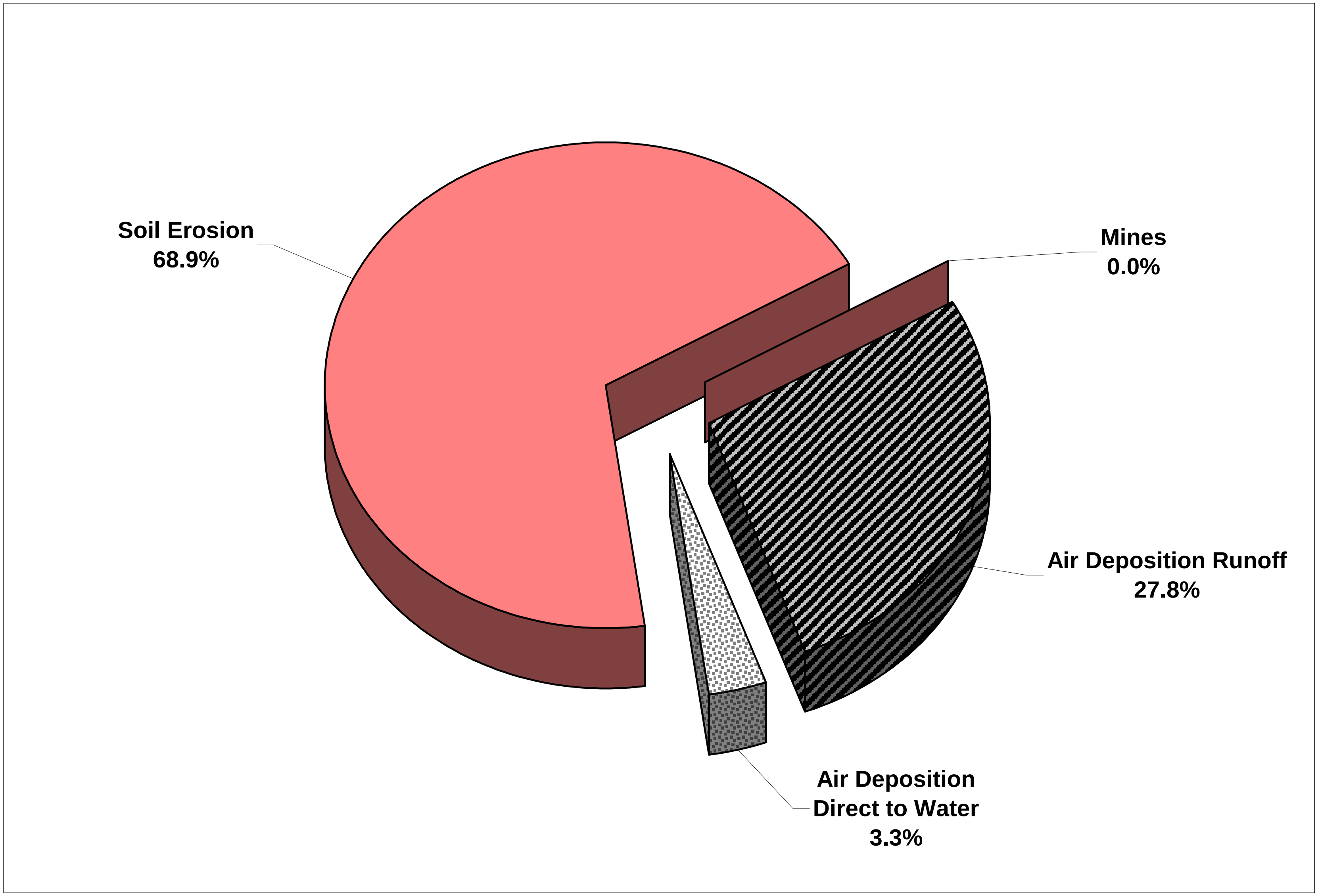


**Figure 3.7** **Relative Source Load Contributions for the Dorena Watershed (Total Load = 2.08 kg/yr)**



## Seasonal Variation and Critical Condition

As noted above, the annual averages in the mercury mass loading obscure the considerable variation in mass loads that are driven primarily by seasonal changes in flow rates. Because mercury binds to particles, there is a positive relationship ($R^2 = 0.56$) between total suspended solids (TSS) and total (unfiltered) mercury concentrations (Figure 3.8), with only a moderate ($R^2 = 0.45$) relationship for dissolved mercury concentrations. In the wet season, increases in soil erosion due to storm events and resuspension of bed sediment (by the higher shear velocities associated with higher flow rates) combine to produce higher TSS levels. Because mercury is both contained in, and bound to, soil and sediment particles, higher total mercury loads are evident during the wet season (Figure 3.9).

The bioaccumulation of mercury in fish is a long-term chronic effect and it would most likely take several seasons for a fish to accumulate enough methyl mercury to attain or exceed the threshold level for the issuance of fish consumption advisories. Summer conditions, however, may provide favorable conditions for the conversion of inorganic forms of mercury to methyl mercury by bacteria, a process known to be temperature-dependent (Ullrich *et al*., 2001). A more elaborate mercury mass balance analysis will need to be developed to more fully account for the seasonal variation affecting mercury loading and methyl mercury bioaccumulation and to determine how best to incorporate seasonal variation into the mercury TMDL. This analysis is being proposed for the second phase of this TMDL scheduled for completion in 2011.

**Figure 3.8** **Relationship Between Total and Dissolved Mercury and Total Suspended Solids in the Mainstem Willamette River.**

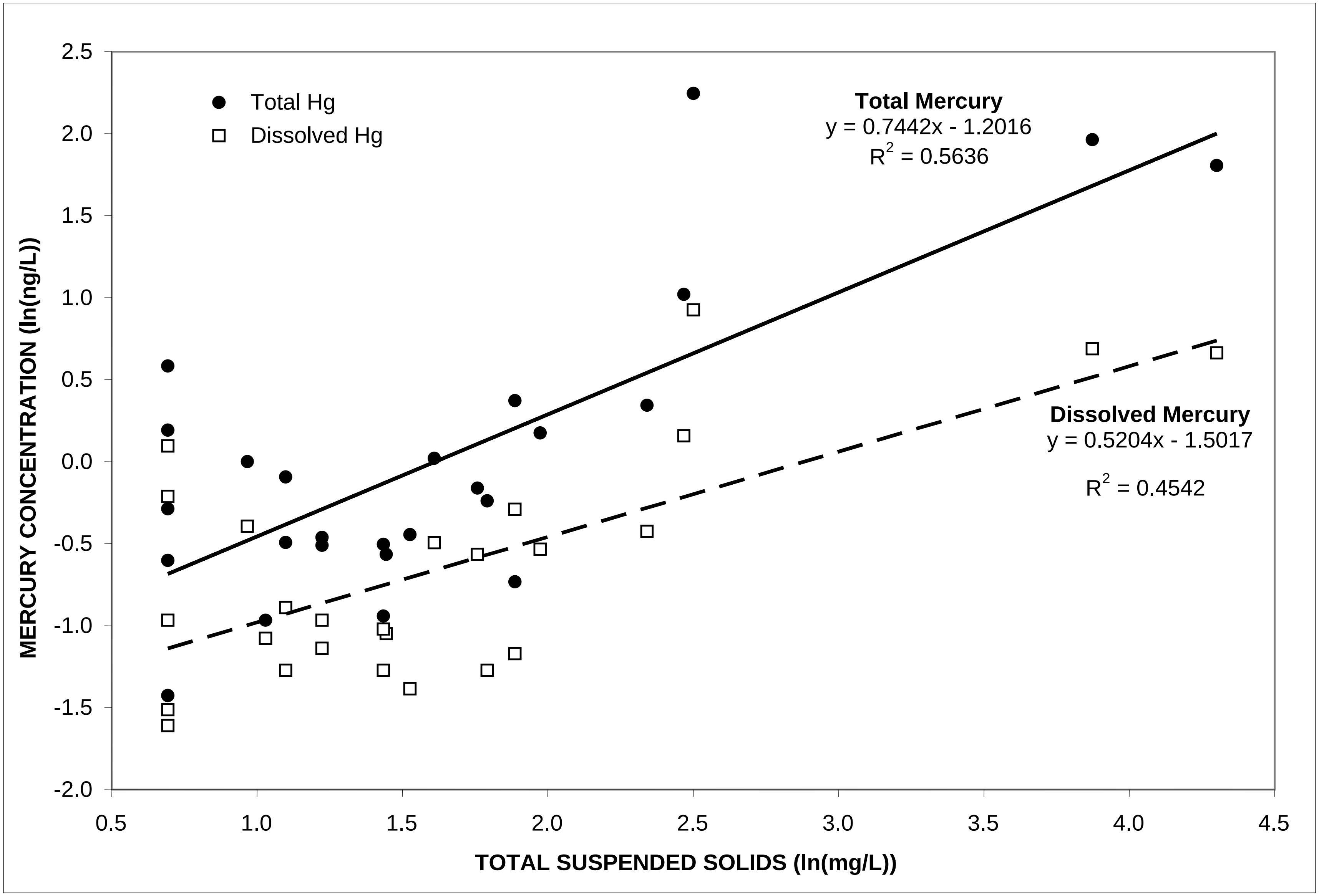
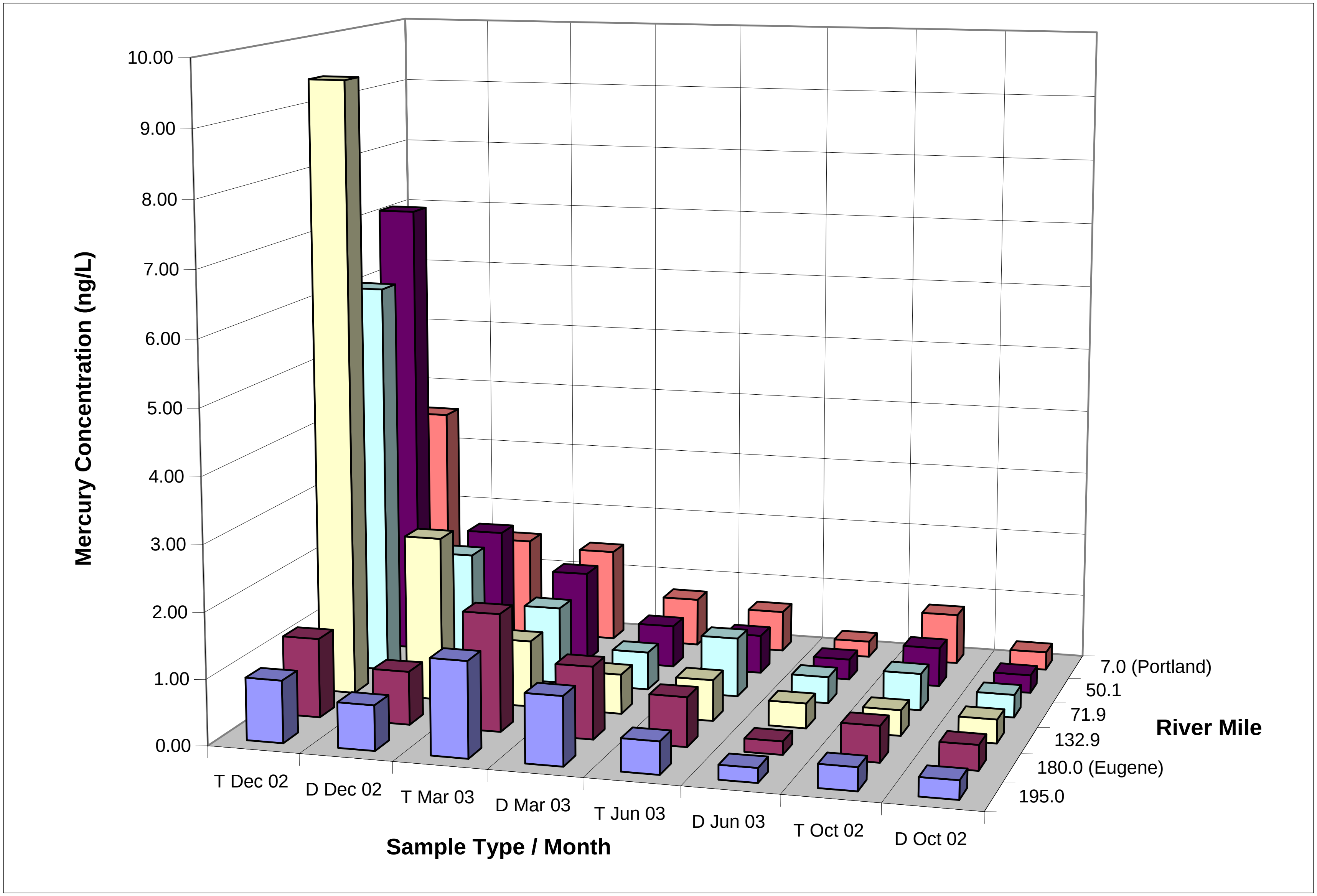


**Figure 3.9** **Seasonal and Spatial Trends in Total (T) and Dissolved (D) Mercury Concentrations in the Mainstem Willamette River.**



# Loading Capacity

The loading capacity provides a reference for calculating the amount of pollutant reduction needed to restore the beneficial use of fish consumption in the Willamette Basin. The loading capacity, presented here in units of total mercury, represents the load of total mercury (in kg/yr) associated with the interim water column guidance value concentration deemed to be protective of the beneficial use of fish consumption. The derivation of this loading capacity relies on both the Basin-Specific Aquatic Food Web Biomagnification Model for Estimation of Mercury Target Levels and the estimate of mercury mass loads discussed above and presented in Appendix B.

The interim water column guidance value for total mercury (generated by the FWM) has been used to establish the estimated percent reduction needed in the load of total mercury to waters of the Willamette. For the purpose of this preliminary analysis, it is assumed that a given percent reduction in mercury mass loading will result in a linear percent reduction in water column concentrations. The various processes governing mercury speciation and transformation in the Willamette River system are complex rate-dependent processes that are poorly understood and it is difficult to predict with complete certainty how the concentrations of the various species of mercury will change with decreases in total mercury loading. The basic assumption utilized in this mass balance approach, however, is that water column concentrations will decline as source contributions decrease. The validity of this assumption will be addressed in future studies as a component of the adaptive management process (see below).

## *Water Column Guidance Value*

The FWM was employed to establish a range of interim guidance values for total mercury and methyl mercury in surface water as described above and in Appendix B. These interim water column guidance values are linked to the restoration of the beneficial use of fish consumption. Several mercury guidance values for the Willamette Basin were generated varying in their probability of affording human health protection relative to the established fish tissue criterion. These interim guidance values are presented in Table 3.3 (for total mercury) and Table 3.4 (for methyl mercury) in the *Pollutant and Target Identification* section of this document. It should be noted that the FWM based its analysis on an acceptable fish tissue concentration of 0.3 mg/kg, as opposed to the 0.35 mg/kg utilized by the DHS in issuing their fish consumption advisory. The 0.3 mg/kg value was based on recent USEPA guidance establishing 0.3 mg/kg as the appropriate fish tissue criterion for methyl mercury (USEPA, 2001a). The use of 0.3 in our analysis, as opposed to 0.35, can be considered an explicit (15%) margin of safety (MOS).

Different fish species will bioaccumulate mercury to varying degrees based primarily on differences in their dietary patterns. The upper trophic level (piscivorous) predators like the bass and the northern pikeminnow are known to exhibit higher degrees of mercury bioaccumulation. This TMDL establishes an interim water column guidance value for mercury based on the biomagnification associated with an upper level predator namely, the northern pikeminnow (also known as squawfish). Whereas some may consider this to be an overly conservative decision, the guidance values presented in this TMDL need to address the specific species listed in the original DHS fish consumption advisory for the Willamette River, namely bass and the northern pikeminnow. Based on the results of the FWM, if the water column guidance value associated with the northern pikeminnow is attained, consumers of other fish species (including the largemouth and smallmouth bass) will also be protected. The choice of the northern pikeminnow as the basis of the water column guidance value is further validated by recent studies suggesting that northern pikeminnow are indeed consumed, although not specifically targeted by recreational or subsistence fishermen (Adolfson, 1996; EVS, 1999; DHS 2003). The pikeminnow itself is abundant throughout the mainstem Willamette system, easy to catch (as opposed to bass) and grows to be quite large. As a result of these factors, northern pikeminnow caught from the Willamette River system are known to be consumed on an occasional basis.

The FWM calculates a range of water column guidance values for each fish species considered varying in their degree of protectiveness for human consumers. If a water column guidance value associated with the fifth percentile were to be selected, there would be a five percent chance that a fish from that particular fish species would have a tissue concentration of mercury at or below the 0.3 mg/kg threshold. At guidance values corresponding to the ninety fifth percentile, there would be a ninety five percent probability that the fish would have a concentration at or below the 0.3 mg/kg threshold. ODEQ proposes to use the median value for the northern pikeminnow as the basis for the interim water column guidance value. The utilization of the median value is consistent with the various fish consumption advisories issued by the DHS which are based on average levels of mercury in fish. The median value for the northern pikeminnow corresponds to a greater degree of protectiveness for consumers of bass and other fish caught from the Willamette. The median value for the northern pikeminnow is basically equivalent to the 57$^{th}$ and 73$^{rd}$ percentile values for the largemouth and smallmouth bass, respectively.

The water column guidance value for total mercury (associated with the median value for the northern pikeminnow) is 0.92 ng/l (Table 3.3). If this guidance value were reached fifty percent of the time in the Willamette mainstem system, then our analysis predicts that average fish tissue concentrations of mercury in the northern pikeminnow will eventually fall below the threshold of 0.3 mg/kg thereby eliminating the need for fish consumption advisories pertaining to mercury.

## Preliminary Estimate of the Necessary Percent Reduction

ODEQ's ambient monitoring data were used to estimate the mean annual concentration of total mercury in the mainstem Willamette River. Five sites in the mainstem Willamette River were sampled on a quarterly basis to obtain an average annual mercury concentration (total, unfiltered) of 1.25 ng/l (Appendix B). For the purpose of this analysis, the geometric mean was used as the most appropriate statistical measure of average ambient conditions. (The geometric mean more closely approximates the median of log-normally distributed data and is less sensitive to the extreme values recorded during high flow events.) This average annual mercury concentration (1.25 ng/l) was then compared to the interim water column guidance value (0.92 ng/l; the number associated with the median value for the northern pikeminnow) to obtain an estimate of the percent reduction in water column concentrations in the Willamette needed to attain the interim water column guidance value. If we were to attain a 26.4 % reduction in ambient total mercury concentrations in the Willamette River, then based on our modeling and the assumptions inherent in this approach, there would be a 50 % likelihood that a northern pikeminnow taken from the Willamette would have a fish tissue concentration less than 0.3 mg/kg. As mentioned before, if the water column guidance value associated with the northern pikeminnow were attained, consumers of largemouth and smallmouth bass would also be protected.

The estimated annual mean rate of mercury inputs in the mainstem Willamette River System is approximately 128.5 kg/yr (as presented in Table 3.5 in the *Mercury Mass Loads* section of this document). According to the hypotheses outlined above, it is assumed that a given percent reduction in the mercury mass load will result in a linear percent reduction in water column concentrations. In other words, a 26.4% reduction in the loading of total mercury would eventually lead to a corresponding reduction in water column concentrations. A 26.4% reduction in the average annual load of mercury corresponds to a 33.9 kg/yr reduction in total mercury loading to the Willamette system and a loading capacity of 94.6 kg/yr. This loading capacity represents the maximum amount of total mercury that the Willamette River can absorb on an average annual basis and still meet the beneficial use of fish consumption. If additional information suggests that any of the assumptions outlined above are not valid, then the loading capacity and the necessary percent reduction presented in this section would be modified as part of the iterative adaptive management process.

An analogous process was used to calculate the loading capacity and the required percent reduction for the watersheds above the Dorena and Cottage Grove Reservoirs. For the Dorena watershed, the estimated total mercury mass load is 2.08 kg/yr. The average annual water column concentration in Dorena Reservoir is 1.31 ng/l necessitating a 29.8% reduction to attain the water column guidance value of 0.92 ng/l. A 29.8% reduction in loading for this system corresponds to a loading capacity of 1.46 kg/yr and a required load reduction of 0.62 kg/yr.

For the Cottage Grove Watershed, the estimated total mercury mass load is 3.13 kg/yr. The average annual water column concentration in Cottage Grove reservoir is 2.86 ng/l necessitating a 67.8% reduction to attain the water column guidance value of 0.92 ng/l. A 67.8% reduction in loading for this system corresponds to a loading capacity of 1.01 kg/yr and a required load reduction of 2.12 kg/yr. As illustrated in Figures 3.6 and 3.7 of this document, legacy mines do not appear to represent a major continuing source of mercury for the Dorena Watershed but they do represent a significant source of mercury for the Cottage Grove system. Table 3.6 presents a summary of current loads, loading capacities, and necessary percent reductions for the mainstem Willamette River, Cottage Grove and Dorena systems.

It should be noted that the current estimates of the annual ambient concentration of total mercury in the mainstem Willamette and the Dorena and Cottage Grove Reservoirs are based on quarterly data from a single monitoring year. Continued ambient monitoring will help refine the estimates of annual average mercury concentrations and the percent reductions necessary to attain the water column guidance values.

**Table 3. 6 Loads, loading capacities and percent reductions for waterbodies considered in this analysis.**

| Waterbody | Estimate of current average annual load (kg/yr) | Loading capacity (kg/yr) | Required percent reduction in total load to attain the loading capacity |
|---|---|---|---|
| Mainstem Willamette | 128.5 | 94.6 | 26.4 |
| Dorena Watershed | 2.08 | 1.46 | 29.8 |
| Cottage Grove Watershed | 3.13 | 1.01 | 67.8 |

## Interim Wasteload and Load Allocations

The source characterization presented in Appendix B presents an estimate of the average annual loading of mercury from various source categories including atmospheric deposition, soil erosion, abandoned mines, and municipal and industrial discharges. As mentioned previously, the urban stormwater component is contained within the estimates of runoff from atmospherically deposited mercury and the erosion of native mercury containing soils.

Interim wasteload allocations are assigned to source sector categories as opposed to individual point sources within a sector. This policy decision is based on the significant uncertainty that exists concerning mercury's behavior in the environment, the precise contribution from individual point sources (adding or contributing to the standards violation), and the effectiveness of potential implementation activities. Given these factors, ODEQ sees no benefit in developing wasteload allocations at a level of detail finer than the sector-wide allocations presented in this TMDL or to develop individual numeric NPDES permit limits, at this point in time. Point sources within a sector will be required to develop mercury minimization plans and to monitor their effluent to better characterize their contribution of mercury and the effectiveness of management measures. The implementation of best management practices (BMPs) should allow point sources to meet the overall allocation for the specific sector. Nonpoint source sectors will be expected to implement mercury reduction activities via the established programs presented in the Water Quality Management Plan (see Chapter 14). The effectiveness of these BMPs in attaining sector-wide allocations will be evaluated over time as part of the adaptive management framework.

The summary balance of mercury inputs are presented in Table 3.5 and the relative source load contributions for the mainstem are presented in Figures 3.3 and 3.4. Each of the categories considered in the source characterization analysis has been given an interim allocation consistent with the need to reduce total mercury loading by 26.4% (see above). The addition of a small reserve capacity of 0.6% to account for growth and/or new sources (see below) brings the required percent reduction for the mainstem Willamette sources to 27%. ODEQ is proposing an ‘across the board’ reduction of 27% for *each* of the source categories considered in the analysis. A prorated or proportional allocation framework was at one time being considered for this TMDL but a number of members of the Willamette Basin TMDLs Council felt that an across the board reduction framework was more equitable and justifiable given the limited information available. The sum of the wasteload allocations (for point sources), the load allocations (for nonpoint sources), and the reserve capacity is equal to the loading capacity for the system. In order to achieve the guidance value for mercury in the mainstem Willamette system, the sum of all loads from the various source categories would need to be equal to or less than the loading capacity of 94.6 kg/yr.

The estimated current loads and interim allocations for each of the source sector categories considered in the Source Characterization analysis are presented in Table 3.7. The sum of the current loads is 128.5 kg/yr and the sum of the allocated loads is 93.8 kg/yr, representing a 27% reduction from current levels. The total current loads into the Dorena and Cottage Grove Reservoirs are 2.08 and 3.13 kg/yr, respectively. Allocations for the Dorena and Coast Fork watersheds are presented in Table 3.8. Interim load allocations for the Dorena and Cottage Grove watersheds are 1.46 and 1.01 kg/yr, respectively.

The estimated load of total mercury from all known and currently quantified point sources (5 kg/yr) represents approximately 4% of the total load of mercury in the mainstem Willamette River system. Due to the fact that the impairment of the Willamette River is due primarily to nonpoint sources associated with either atmospheric deposition or the erosion of mercury containing soils, the complete elimination or significant reduction of mercury from water point source discharges would not be enough to attain the interim water column target. In other words, even if this TMDL were to allocate none of the calculated allowable load to NPDES point sources (i.e. a wasteload allocation of zero), the applicable water column targets for mercury would not be attained because of the very high mercury loadings from nonpoint sources. At the same time, however, ODEQ recognizes that mercury is an environmentally persistent bioaccumulative toxic substance that should be eliminated from discharges to the extent practicable. In this initial phase of the TMDL, ODEQ expects that point source loadings of mercury would be reduced primarily through mercury minimization programs developed and implemented by industrial and municipal point sources. Eliminating the point source discharges of mercury (through a wasteload allocation of zero) would have little overall effect on water quality and would cause much economic hardship. Furthermore, reducing point source loadings beyond the levels contemplated by the cumulative wasteload allocation would not be necessary to achieve the interim water column targets.

The analysis presented in this document suggests that no one source category is entirely responsible for the mercury contamination in the Willamette Basin. Collaborative efforts extending across all source categories (both point and nonpoint) will be necessary to achieve reductions in mercury loading and, ultimately, the restoration of the beneficial use of fish consumption. A description of the various implementation activities designed to achieve cross-sector reductions in the load of total mercury are presented in detail in the Water Quality Management Plan (see Chapter 14).

**Table 3. 7 Estimated Current Loads and Interim Mercury Allocations for the mainstem Willamette River System.**

| Source Sector Category | Estimated Load of Total Hg (kg/yr) | Interim Allocation Load or Wasteload (kg/yr) |
|---|---|---|
| ***Nonpoint Sources (assigned interim load allocations)*** | | |
| Runoff of atmospherically deposited mercury | 53.7[(a)] | 39.2 |
| Direct deposition to open water | 7.6 | 5.5 |
| Erosion of mercury containing soils | 61.4[(a)] | 44.8 |
| Legacy mine discharges | 0.8[( b)] | 0.6 |
| Sediment re-suspension (input to water column) | 0.0 [(c)] | 0.0 [(c)] |
| ***Point Sources (assigned interim wasteload allocations by sector)*** | | |
| POTW Discharges | 3.5 | 2.6 |
| Industrial Discharges | 1.5 | 1.1 |
| **Sum of Current or Allocated Loads** | **128.5** | **93.8** |
| **Reserve Capacity** | NA | 0.8[(d)] |

(a) The estimate of the total mercury load for this source category includes a component attributable to stormwater discharges from urbanized areas. These stormwater inputs may originate in either MS4 communities or non-MS4 communities and includes the overland flow of mercury directly into impacted waterbodies. In certain situations these loadings may be considered to be point sources, as in the case of MS4 discharges, but for the purpose of this analysis, the stormwater component is contained within the 'runoff of atmospherically deposited mercury' and 'erosion of mercury containing soils' categories and is accounted for here as a nonpoint source category.

(b) The contribution from legacy mines is considered to be a nonpoint source input due to the reasons outlined in the text of this document.

(c) Seasonal average value, expected to be significantly higher during the wet (high flow) season.

(d) The sum of the allocated loads and the reserve capacity is equal to the loading capacity of the system (94.6 kg/yr).

**Table 3. 8 Estimated Current Loads and Interim Mercury Allocations for the Cottage Grove and Dorena Watersheds.**

| Source Sector Category | Estimated Load of Total Hg (kg/yr) | Interim Allocation Load or Wasteload (kg/yr) |
|---|---|---|
| ***Cottage Grove Watershed*** | | |
| Runoff of atmospherically deposited mercury | 0.22 | 0.07 |
| Direct atmospheric deposition to water | 0.03 | 0.01 |
| Erosion of mercury containing soils | 0.55 | 0.18 |
| Legacy mine discharges | 2.33 | 0.75 |
| ***Sum of Current or Allocated Loads for CG Reservoir*** | **3.13** | **1.01**[b,c] |
| ***Dorena Watershed*** | | |
| Runoff of atmospherically deposited mercury | 0.58 | 0.41 |
| Direct atmospheric deposition to water | 0.07 | 0.05 |
| Erosion of mercury containing soils | 1.43 | 1.00 |
| Legacy mine discharges | ND[a] | ND[a] |
| ***Sum of Current or Allocated Loads for Dorena Res.*** | **2.08** | **1.46**[b,d] |

(a) ND = Not Determined; no data currently available with which to estimate an actual value or to assign an interim load allocation. In the event new information allows us to quantify a load attributable to legacy mining discharges, the estimated rates for the runoff of atmospherically deposited mercury and the erosion of mercury containing soils will be adjusted accordingly. The sum of the current loads would not change.
(b) The sum of the allocated loads is equal to the loading capacity of the system.
(c) For the Cottage Grove Watershed, a total reduction of 67.8% is needed to attain the interim water quality guidance value.
(d) For the Dorena Watershed, a total reduction of 29.8% is needed to attain the interim water quality guidance value.

## Margin of Safety

The FWM employed in this TMDL utilizes a fish tissue criterion of 0.3 mg/kg in establishing water column targets consistent with current USEPA recommendations. The DHS, on the other hand, employed a threshold of 0.35 mg/kg in edible fish tissue in issuing their fish consumption advisories (DHS, 1993, 1997a, 1997b, 2004a, 2004b). The use of the lower more conservative 0.3 mg/kg represents a conservative margin of safety on the order of 15%. The selection of the interim water column guidance value was also conservative by nature as we have utilized the northern pikeminnow, the most efficient bioaccumulator considered in our model. In selecting a guidance value based on the northern pikeminnow, we have chosen one that is also protective of consumers of other fish species that are more readily consumed by anglers. For example, the median guidance value associated with the northern pikeminnow would correspond to the 57th percentile value for the largemouth bass. In other words, at the guidance value utilized in this analysis (0.92 ng/l), 57% of the largemouth bass would be expected to exhibit fish tissue concentrations at or below 0.3 mg/kg.

## Reserve Capacity

The reserve capacity is an allocation set aside for increases in pollutant loads from future growth and/or new or expanded sources. ODEQ has the discretion of issuing (or choosing not to issue) a reserve capacity. ODEQ has incorporated a small reserve capacity of 0.8 kg/yr (0.6% of the total estimated load) in this TMDL analysis for mercury. This small reserve capacity would allow a growing municipality or a new source to discharge effluent containing low levels of mercury. ODEQ, however, does not anticipate major increases in mercury loading in the near future. Mercury has been identified as a persistent bioaccumulative chemical of concern and many actions are currently occurring throughout the region to minimize the use of mercury in products and to remediate sites contaminated with mercury. These cross programmatic actions to reduce mercury discharges are outlined in ODEQ's Mercury Reduction Strategy (ODEQ, 2003a). Measures to minimize soil erosion from agricultural areas, forested environments, and construction sites are currently being implemented throughout the basin. In addition, there are no longer active mercury mines in the Willamette Basin and the use of mercury in gold and silver mining has been curtailed. The incorporation of this small reserve capacity in this TMDL analysis changes the total required percent reduction from the various sectors from 26.4% to 27%.

## Adaptive Management

ODEQ recognizes that a number of assumptions were made as part of this TMDL process and that gaps in our understanding of mercury's sources and fate and transport still exist. For example, little is known regarding the precise rates and locations of mercury methylation in the Willamette Basin. A more detailed mass balance analysis is needed to better understand how mercury cycles within the Willamette Basin. A mass balance analysis for mercury, considering both anthropogenic and natural inputs as well as the partitioning of mercury into discreet environmental media, will permit a more complete and representative accounting of the relative contributions of total and methyl mercury to the Willamette River system. Without a comprehensive numeric model such as this, it is difficult to assess the relative percentages of total and methyl mercury mass loads from natural and anthropogenic sources. A calibrated model would also allow us to predict the effectiveness of remediation efforts or sector-specific source category reductions in terms of ultimately achieving reduced environmental/fish tissue concentrations. Additional information is also needed to better understand the significant seasonal variations known to affect mercury loading and methylation in the Willamette River system.

ODEQ expects to work with its stakeholders over time to help fill any remaining data gaps and to refine the interim targets and policy recommendations presented in this document. Potential projects include: refining our estimate of sediment resuspension; quantifying tributary inputs; identifying sinks and sources of mercury; determining the systems responsiveness to decreases in mercury loading; and clarifying how much of the mercury associated with each source category is actually bioavailable for uptake into aquatic organisms. It will also be essential to incorporate additional ambient data and more extensive source data (on total mercury and dissolved methyl mercury concentrations and discharge rates) from key major industrial, municipal and stormwater source categories. The lack of adequate information on mercury source contributions from the various source categories mentioned above is a significant limitation of this TMDL.

The WQMP associated with this TMDL (see Chapter 14) provides a well-defined framework for gathering additional information related to mercury and conducting additional analyses with the ultimate goal of releasing *revised* guidance values and allocations by the end of 2011. The activities presented in the WQMP will help address some of the remaining unknowns and reduce some of the inherent uncertainties. ODEQ also commits to further evaluation of the methodological and modeling tools employed in this study. In the event new information suggests improved alternative methods for establishing guidance values and/or load allocations, this information will be incorporated into the 2011 revisions as part of the adaptive management framework.

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